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Bureaucratic Productivity:

The Case of Agricultural Research

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Among the most consistent themes in the new literature on public economics is the inference that the output of bureaucratic services tends to be excessive, both (a) relative to the equilibrium level of output if the same services were provided by private firms operating in a competitive market and (b) relative to the level of output preferred by the typical legislator and the typical voter. This perspective is perhaps most fully developed in the work of William A. Niskanen, Jr. (1968, 1971, 1975).[1/] It has become pervasive among a broad segment of the public economics school (Borcherding, 1977). The purpose of this paper is to confront the excess supply hypothesis with the large body of evidence that has accumulated on the rate of return to public sector agricultural research.

The Excess Supply Hypothesis

Niskanen's innovation was to supplement the theory of demand for government services in a representative government with a new theory of the supply of bureaucratic services. The approach has involved combining the theory of representative government with a theory of bureaucracy based on the model of bilateral monopoly in which the "bureau sells its

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service to the government and the government buys the service only from the bureau" (Niskanen, 1968, p. 618).

In his initial work Niskanen assumed that the bureau manager's utility function was a positive function of the bureau's output. Niskanen also argued that legislative organization (the committee system) biases the demand for the bureau's services in an upward direction since the membership of legislative committees (the purchaser) is chosen in such a manner that committee members prefer a higher level of output of the particular bureau that they supervise than the typical legislator. Following criticism by Migué and Bélanger the assumption regarding the bureau manager's utility function was modified to include the bureau's discretionary budget (the difference between the total budget granted by a legislative appropriations committee and the minimum cost of producing the expected output) in the bureau manager's utility function (Niskanen, 1975). Incorporation of the Migué and Bélanger utility function modification implies that output will be larger and costs will be higher than if the same product were produced in the private sector.[2/] Orzechowski (1977:248) argues that in addition to larger output and higher costs the bureau will have a higher labor-capital ratio than other institutional forms.

In his article in the Journal of Law and Economics (1975) Niskanen reviews a number of empirical studies which he interprets as consistent with the excess supply hypothesis. The tests are typically based on comparisons of rates of growth of expenditures, comparative costs of services, capital output ratios and other partial measures (Niskanen, 1975, pp. 630-642). Orzechowski has also reviewed a number of studies, including some of those included in the Niskanen review, and concludes that bureaus tend to operate at costs above private alternatives, exhibit slow or negative productivity growth, and use labor-biased techniques of production. Data on rates of return, which might provide a more adequate test of the over-supply hypothesis, were not available in the studies reviewed by Niskanen and Orzechowski. In this paper we draw on the very extensive set of rate of return studies for investment in public sector agricultural research (table 1) to test the excess supply hypothesis.[3/]

The assumptions of the modified Niskanen model would appear to be consistent with the manner in which one might describe (a) the research bureaus of the U.S. Department of Agriculture or (b) the state agricultural experiment stations. The major research bureaus of the USDA were initially established in a manner to take full advantage of the link between the bureau's mission and its clientele interests both within and outside of the Congress.[4/] The capacity of the USDA agricultural research system to mobilize support for program expansion has been maintained through a series of reorganizations. There is some indication, however, that since the reorganization of 1972, which resulted in a more decentralized administrative structure, the Agricultural Research Service (ARS) has become less effective in extracting additional resources than in resisting budget reductions recommended by the Department administration and the Office of Management and Budget (OMB).[5/]

The state agricultural experiment stations and extension services are also characterized by an intimate relationship with committees of the state legislatures. Both the stations and the legislatures are in turn closely linked to organized clientele groups whose members are the primary users of the new knowledge and new technology that is developed at the experiment stations and disseminated by the extension services.[6/]

From personal observation I have no trouble identifying the behavior of the Agricultural Research Service administrator or state agricultural experiment station director with the Niskanen bureaucratic manager who attempts to maximize some combination of budget size and discretionary budget. The ARS has a degree of discretionary authority that many other agencies lack. It has a trust fund, some permanent authorizations, and generates some contributions for its research from outside the federal government. The effect is to free a portion of the ARS budget from the annual appropriation process. A state experiment station director who manages an effective program of applied research which has a sufficiently high payoff to his rural clientele to reinforce the interest of the legislature in the work of the experiment station is also typically rewarded with a "discretionary" budget from state sources or from federal and private grant sources which can be used to support the more basic research which has a longer-term payoff both in terms of the productivity of applied research and in the prestige of the experiment station.

Evidence on Underinvestment in Agricultural Research

In contrast to the excess supply hypothesis suggested by the Niskanen public economics model, the rate of return studies, for both individual commodities or factors and for total research systems, suggest underinvestment rather than overinvestment in agricultural research. The observed annual rates of return typically fall in the 30-60 percent range (table 1). It is hard to imagine very many investments in either private or public sector activity that would produce more favorable rates of return.[7/] [8/] There is little doubt that a level of expenditure that would push rates of return to below 20 percent would be in the public interest.

The high rate of return estimates for investment in agricultural research obtained in most of the studies summarized in table 1 forces to the surface several questions about their apparent inconsistency with the inferences of the public economics model. Why, given the plausible nature of the assumptions of the public economics model and at least superficial consistency between the model assumptions and an institutional counterpart, does society underinvest rather than overinvest in public sector agricultural research? Several hypotheses can be suggested. Before doing so, however, it is worth addressing the question of the accuracy of the rate of return estimates. If there is serious upward bias in the rate of return estimates, it may be possible to avoid questions regarding their implications for the public economics model or for research planning and policy.

Accuracy of Rate of Return Estimates

How accurate are the rate of return estimates? It seems apparent that the presentation of the results of the early hybrid corn and sorghum studies in the form of "external" rather than "internal" rate of return estimates often resulted in confusion concerning the interpretation and skepticism regarding the validity of the estimates.[9/] There have also been several major methodological criticisms of the rate of return studies. One is that they have often failed to take into consideration the complementary technical inputs and the related marketing and extension education costs incurred in order to realize the productivity gains resulting from the adoption of the new technology (Wise, 1975). A second criticism is that the rate of return estimates are highly sensitive to assumptions about the form of the supply curve shift that is associated with adoption of the new technology.[10/]

Some critics have also argued that an exaggerated impression of the rate of return has resulted from the selection of a few cases of spectacular research success such as hybrid corn.[11/]

It is clear that the assumptions employed in several of the early rate of return studies, particularly those conducted within the index number tradition, did lead to exaggerated rate of return estimates. The assumptions about the role of complementary inputs and the slope of the supply curve were particularly critical in the Griliches hybrid corn studies. The criticisms do not apply with the same force to the more recent index number studies or to the studies that have been conducted within the production function tradition. Most of the more recent index number studies have assumed a divergent shift in the supply curve. Any bias introduced by this assumption has the effect of underestimating the true rate of return. The production function studies have explicitly taken into account the complementary effects of related inputs, and the newer index number studies have typically given more careful attention to budgeting the costs of complementary inputs. A number of studies are now available within both traditions that estimate rate of return to national research systems rather than to individual commodities. There is also a tendency, since the important study by Schmitz and Seckler (1970) of tomato harvesting in California, to consider the distributional implications of agricultural research.

A review of the body of literature summarized in table 1 impresses one with the increasing degree of sophistication that the authors of the more recent studies have displayed in responding to the limitations of the earlier studies. The effect of more careful model specification, more complete measurement of costs and greater caution in estimating benefits has, in my judgment, led to results which tend to under rather than overestimate the return to agricultural research. I am forced to conclude that is is not possible to avoid a confrontation between the implications of the Niskanen version of the public economics model and the results of agricultural research rate of return studies. The problem remains how to explain the high rate of return to public sector agricultural research rather than the overinvestment suggested by the public economics model.

Two Hypotheses

I would like to suggest two possible hypotheses for the high rate of return to public sector agricultural research. One is the efficient allocation of resources to research. The second is underinvestment due to lack of congruence between the costs and benefits from research.

Efficient allocation of resources to research

Niskanen has suggested that one structural change which would reduce the incentives for excess supply "would be to increase competition among bureaus in the supply of the same or similar services" (Niskanen, 1971, p. 195). As noted earlier, the United States is characterized by both federal and state agricultural research systems. In recent years over 70 percent of the funding of the state system is appropriated by the state legislatures. Most of the federal support for state agricultural research is allocated to the states by a formula based on the number of farms and the size of the rural population. Furthermore the research activities of the national agricultural research system administered by the U.S. Department of Agriculture are, because of the location specific nature of agricultural research, conducted at widely dispersed locations, and often in cooperation with the state research system.

We have, therefore, a public sector agricultural research system that, in addition to an industry leader that operates under a decentralized management system (the USDA-ARS), includes 50 state level "firms" whose output is viewed by its clientele as an input into state economic development. It seems reasonable to expect that a system of agricultural research, organized along lines roughly consistent with the competitive model, helps explain why the U.S. public sector agricultural research is induced to select a high payoff research portfolio when measured by the contribution of the research output to state economic growth. The short feedback loop between the experiment station, farm and agribusiness clientele, and the appropriation process in state legislatures appears to induce a pattern of research resource allocation on the part of state experiment stations that simulates portfolio choice behavior that is consistent with the behavior expected from firms in a competitive market. These pressures induce the director of the Minnesota agricultural experiment station, for example, to allocate the resources available to him in a manner that will enable Minnesota farmers to remain competitive with Iowa corn producers, Illinois soybean producers, and Wisconsin dairy farmers.[12/]

The "competitve" organization of the U.S. agricultural research industry may help explain the research resource allocation process leading to the selection of an "efficient" research portfolio. However, it does not go very far in helping us to understand the underinvestment in agricultural research implicit in the high rates of return suggested in table 1. If the USDA-state agricultural research system is efficient and continues to achieve high rates of return, why does the political process, motivated by organized producers and their legislative allies, continue to undervalue and to underinvest in public sector agricultural research?

Spillover effects and free riders

A second possible area in which to search for an explanation of the underinvestment in agricultural research lies in the spillover effects and the resulting lack of congruence between the costs and the benefits of agricultural research. There are two important dimensions to this problem.

One dimension stems from the fact that the research that is paid for by one state can be expected to have an impact on productivity growth in other states. Much of agricultural research, particularly at the applied end of the research and development spectrum, is highly specific to particular agro-climatic regions. However, several recent studies have demonstrated substantial spillover effects among states and nations in the area of basic and supporting research.[13/]

It might be argued that it should be precisely the function of the USDA Agricultural Research Service to focus its efforts in those areas of basic and applied research where geographic spillover limits the incentive for individual states to invest in research. However, it is my impression, and that of others, that the USDA agricultural research system is even more oriented to applied research than the state system.[14/] This may reflect the interests of commodity based clientele groups which tend to support the research program of the USDA in contrast to the more general area based support for the state agricultural experiment stations.

The formula funding arrangement requires the states to match the federal support for state research. This represents, in effect, partial compensation to the individual states for the benefits other states, and the nation, receive from state agricultural research. The smaller states, which tend to capture the smallest share of the benefits from research in their own states, tend to allocate only enough funds to agricultural research to meet federal matching requirements. The larger states appropriate substantially greater amounts for agricultural research than the federal formula funding requirements. For example, in 1975 the California agricultural experiment station received $2.4 million in federal formula funds and $33.9 million in state appropriations. The Illinois station received $2.3 million in federal formula funds and $6.5 million in state appropriations.[15/]

It seems quite clear, however, that the present matching arrangement does not induce an optimum level of state appropriations for agricultural research. Other formula arrangements might be considered that would more effectively compensate the individual states for the benefits that spill over into other states and that would induce a more efficient level of state appropriations for agricultural research. One possibility would be to revise the formula to require federal matching of state appropriations rather than the present method which requires state matching of federal appropriations.

A second dimension of the spillover effects of agricultural research is the transfer of the gains from research from producers to consumers. The manner in which the gains from technical change in agriculture are partitioned between the producers and consumers of a particular commodity depends on the slopes of the demand and supply curves for the product and the rates at which the two curves are shifting to the right over time. In a market characterized by highly elastic demand, or by rapid growth in demand, producers are able to retain a relatively large share of the gains from technical change. In a market characterized by inelastic demand and by slow growth in demand, most of the gains from technical change will be passed on to consumers in the form of lower product prices. In high income countries with low rates of growth in demand, such as the United States, some Western European countries, and Japan, the gains from productivity work in agriculture have in the past been rapidly transferred from producers to consumers (Cochrane, 1958; Akino and Hayami, 1975).[16/]

Under competitive market conditions the early adopters of the new technology in the agricultural sector tend to gain while the late adopters are forced by the product market "treadmill" to adopt the new technology in order to avoid even greater losses than if they retained the old technology. One effect of the treadmill phenomenon is, to the extent that it is recognized by farmers, to limit the economic motivation for support of agricultural research to a relatively small population of early adopters of new technology. The early adopters also tend to be the most influential and politically articulate farmers.[17/] Support for agricultural research has not been able to achieve as broad a base among the farm population as support for commodity price programs. Apparently the benefits from commodity price support programs, which have the effect of slowing the transfer of the gains from technical change from producers to consumers, are perceived to have a more immediate impact and to be more broadly shared within the agricultural community than the benefits from agricultural research.

How effective is the transfer of productivity gains from the farm to the nonfarm sector in generating consumer support for agricultural research? Analysis by Peterson (1969) and Huffman (1978) of factors affecting the level of state funds for agricultural research indicates that differences in state nonfarm income have been even more important than state farm income in accounting for variations in state support for agricultural research. On a more disaggregated basis, however, differences in farm income were more important than differences in nonfarm income in accounting for variations in state support for departments engaged in production research (such as agronomy and animal science) while differences in nonfarm income were more important in accounting for variations in support for departments with a public affairs or consumer orientation (such as agricultural economics and horticulture).[18/] This suggests that both consumers and producers tend to support those agricultural research activities with which they have the most direct contact. The relatively sophisticated arguments based on relative shifts in demand and supply functions and on changes in producers and consumers' surplus have apparently been difficult to translate into a language that generates political support from organized producers or consumers. The large gains to consumers as a group are, when partitioned among individual consumers, too small to induce sustained consumer support for production research.[19/] Support tends to emerge during periods of sharply rising prices and to be rapidly dissipated during periods of relative price stability.

If this second hypothesis with respect to the partitioning of gains from agricultural research is correct, it suggests that the underinvestment in agricultural research is due to the weak institutional infrastructure between voters--farm producers and consumers--and politicians rather than to the strong institutional link between bureaucrats and politicians suggested by Niskanen.

Some Implications

The U.S. public sector agricultural research system appears to be relatively efficient in the allocation of research resources. It is, however, far less effective in resource acquisition than is suggested by the Niskanen model. The analysis presented above suggests that both its efficiency in the allocation of research resources and its capacity to mobilize resources are strongly related to its decentralized organization.

A highly centralized system might be expected to be less efficient in allocating resources to research but more effective in resource acquisition. If the system were more highly centralized, a combination of loss in efficiency in research resource allocation and increased funding for research could be expected to drive the returns to agricultural research to more conventional levels.

A clear implication of this paper is the implication that the design of institutional innovations to facilitate the allocation of resources to the provision of bureaucratic services in areas where there is substantial underinvestment by the public sector should remain an important area of economic inquiry. The redesign of the formula for federal support of state research is one possibility that should receive careful attention.

The conservative thrust of much of the new literature on public economics has tended to direct attention primarily to areas of overinvestment and inefficiency in the supply of bureaucratic services. This is a legitimate thrust. But, given present limitations in our understanding of the allocative processes in the political use of economic resources, it should not be permitted to establish an *a priori* presumption that the supply of public services is excessive in the absence of careful empirical investigation. Nor should it, by calling attention to those areas where biases in the incentive structure in the markets where economic and political resources are exchanged impose an excessive burden on economic growth, blind us to the opportunities in those areas where public sector investment has the capacity to open up new and inexpensive sources of growth.

It seems apparent that a general theory of public economics should provide insight into the organization of public activities that lead to efficiency as well as inefficiency in both exchange and production. This is essential if the new public economics is itself to become an efficient source of institutional change.

Table 1. Summary studies of agricultural research productivity

Study	Country	Commodity	Time period	Annual internal rate of return %
Index number				
Griliches, 1958	USA	Hybrid corn	1940-55	35-40
Griliches, 1958	USA	Hybrid sorghum	1940-57	20
Peterson, 1967	USA	Poultry	1915-60	21-25
Evenson, 1969	South Africa	Sugarcane	1945-62	40
Ardito Barletta, 1970	Mexico	Wheat	1943-63	90
Ardito Barletta, 1970	Mexico	Maize	1943-63	35
Ayer, 1970	Brazil	Cotton	1924-67	77+
Schmitz & Seckler, 1970	USA	Tomato harvester	1958-69	
		with no compensation to displaced workers		37-46
		assuming compensation of displaced workers for 50% of earnings loss		16-28
Scobie & Posada, 1978	Bolivia	Rice	1957-64	79-96
Hines, 1972	Peru	Maize	1954-67	35-40[a] 50-55[b]
Hayami & Akino, 1977	Japan	Rice	1915-50	25-27
Hayami & Akino, 1977	Japan	Rice	1930-61	73-75
Hertford, Ardila, Rocha & Trujillo, 1977	Colombia	Rice	1957-72	60-82
	Colombia	Soybeans	1960-71	79-96
	Colombia	Wheat	1953-73	11-12
	Colombia	Cotton	1953-72	none
Peterson & Fitzharris, 1977	USA	Aggregate	1937-42	50
			1947-52	51
			1957-62	49
			1957-72	34
Wennergren & Whitaker, 1977	Bolivia	Sheep	1966-75	44.1
		Wheat	1966-75	-47.5
Production function				
Tang, 1963	Japan	Aggregate	1880-1938	35
Griliches, 1964	USA	Aggregate	1949-59	35-40
Latimer, 1964	USA	Aggregate	1949-59	not sig.
Peterson, 1967	USA	Poultry	1915-60	21
Evenson, 1968	USA	Aggregate	1949-59	47
Evenson, 1969	South Africa	Sugarcane	1945-58	40
Ardito Barletta, 1970	Mexico	Crops	1943-63	45-93

Table 1--Continued

Study	Country	Commodity	Time period	Annual internal rate of return %
Evenson & Jha, 1973	India	Aggregate	1953-71	40
Kahlon, Bal, Saxena & Jha, 1977	India	Aggregate	1960/61-	63
Lu & Cline, 1977	USA	Aggregate	1938-48	30.5
			1949-59	27.5
			1959-69	25.5
			1969-72	23.5
Bredahl & Peterson, 1976	USA	Cash grains	1969	36[c]
		Poultry	1969	37[c]
		Dairy	1969	43[c]
		Livestock	1969	47[c]
Nagy & Furtan, 1978	Canada	Rapeseed	1960-75	95-110
Input demand				
Duncan, 1972	Australia	Pasture improvement	1948-69	58-68

[a]Returns to maize research only.

[b]Returns to maize research plus cultivation "package."

[c]Lagged marginal product of 1969 research on output discounted for an estimated mean lag of 5 years for cash grains, 6 years for poultry and dairy and 7 years for livestock.

Table 1. Sources

The results of many of the studies reported in this table have previously been summarized in

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FOOTNOTES

1/ See also W. Keith Bryant (1972a and b); Jean-Luc Migué and Gerald Bélanger (1974); Albert Breton and Ronald Wintrobe (1975); William Orzechowski (1977); and Gary J. Miller (1977).

2/ "In his initial paper Niskanen assumed that all utility dimensions can be satisfied by maximizing output subject to a budget constraint. Migué and Bélanger argued that such a maximization process involved a contradiction since it implied that zero residuum remained for the utility dimensions specified by Niskanen. On the other hand M-B hypothesized that the bureaus would maximize utility by providing output above minimum costs" (Orzechowski, 1977, p. 240). The Migué and Bélanger extension of the Niskanen model suggested that the bureau is likely to be both exchange and production inefficient--that output will be too large and costs will be too high.

3/ In addition to the public economics literature, which implies excess supply of public services generally, there is one other body of literature which implies low or possibly negative rates of return to public sector investment in research and development. In his work on the theory of information Hirshleifer (1971, 1973) challenges the standard literature on the economics of research and invention that suggests that there tends to be underinvestment in inventive activity, due mainly to the imperfect appropriability of knowledge (Arrow, 1962). He argues that in a world of pure exchange the potential for distributional gains from new knowledge will induce overinvestment in private information (that which can be retained by a single individual or firm). He goes on to point out that in a world that includes both exchange and production, however, gains from new productive arrangements must be offset against the costs of acquisition and dissemination. In this case there may or may not be overinvestment. He argues that in the case of public information (that is available to everyone) some individuals will tend to believe that new information can be used for their private gain. This belief provides an incentive for private individuals to cooperate to produce new information or to induce the public sector to produce new information. Hirschleifer insists that the speculative opportunity is useful in motivating the development and release of new information but that the potential gains eliminate any a priori anticipation of underinvestment in the generation of new technical knowledge.

4/ "The department [of Agriculture] gradually evolved an adequate social and political mechanism . . . The ideal new scientific bureau had clearly defined characteristics. In the first place, the center of interest was a problem, not a scientific discipline. . . . Thus the ideal bureau chief sought continuity by means of a grant of power in the organic act of Congress [establishing the Bureau]. . . . In the second place, the ideal bureau aimed at a stable corps of scientific personnel which was not only competent but also loyal to the Bureau and confident that its work was important to the country. . . . In the third place, the ideal bureau established as harmonious relations as possible with many groups outside itself. . . . The Bureau of Animal Industry thus had most of the attributes of the new scientific agency at its birth--an organic act, a set of problems, outside groups pressing for its interests, and extensive regulatory powers" (A. Hunter Dupree, 1957, 158-159). (See also Charles E. Rosenberg, 1976.) By the early 1900s the scientific bureaus of the U.S.D.A. included the Bureau of Plant Industry, the Bureau of Entomology, the Bureau of Chemistry, the Bureau of Animal Industry, the Bureau of Soils, the Bureau of Biological Survey, the Weather Bureau and the Office of Experiment Stations.

5/ The structure described above remained relatively unchanged, with a Bureau of Agricultural Economics added in 1922, until the early 1950s. In 1953 a major reorganization broke up several of the bureaus and consolidated agricultural research under an Agricultural Research Service (ARS). There have been further modifications since 1953. In 1972 the ARS was reorganized along regional lines with greater decentralized decision making. In January 1978, a further reorganization replaced the Agricultural Research Service by the Science and Education Administration. The Economic Research Service (a successor to the Bureau of Agricultural Economics) was merged into an Economics, Statistics and Cooperatives Service Administration. For a historical review, see Gladys S. Baker, Wayne D. Rasmussen, Vivian Wiser and Jane M. Porter (1963). For a discussion of the capacity of the ARS to mobilize support for budget protection or resource acquisition see Kenneth J. Meier (1977).

6/ For an analytical description of these relationships, see Melvin G. Blase and Arnold Paulson (1972) and Alain de Janvry (1977).

7/ Robert Haveman reports, for example, that of 147 water resource projects constructed in ten southern states between 1946 and 1962, only nine had <u>ex ante</u> rates of return above 20 percent (1965, p. 108). Haveman's more recent work suggests substantial upward bias in the <u>ex ante</u> estimates (1972).

8/ There has been a tendency to assume that the payoff to agricultural extension activities would be lower than to research. However, several recent studies suggest rates of return to extension in the same range as to agricultural research. See Wallace E. Huffman (1976 and 1978) and Abdul Halim (1977). Similar rates of return have also been reported by Yujiro Hayami and Willis Peterson (1972) for the statistical services of the U.S. Department of Agriculture.

9/ When the "external" rate of return method is used, the flows of costs and benefits are accumulated (or discounted) to a point in time using a rate of interest (k) that is intended to reflect the opportunity costs of capital. The research costs are expressed as an accumulated capital sum. The benefits (value of inputs saved) are also accumulated to the same point of time, but are then expressed as a perpetual flow. The external rate of return is obtained by dividing the annual flow of benefits by the accumulated costs (past research expenditures) and expressing the results as a percentage. The external rate of return (r) estimates are directly translated into a benefit-cost (B/C) ratio by $B/C = \frac{r}{100} k$. If the external rate of return is 75, the B/C ratio is 7.5. Thus, the B/C ratio and the external rate of return are just two ways of expressing the same concept. Both the B/C ratio and the external rate of return are highly sensitive to the rate of interest that is chosen to reflect the opportunity cost of capital. The "internal" rate of return avoids this problem. It is the rate of interest which makes the accumulated present value of its flow of costs equal to the discounted flow of returns at a given point in time. The external rate of return to hybrid corn research, estimated by Griliches using a 5 percent opportunity cost for capital, of 743 percent per year converts to an internal rate of return (both calculated to 1955) of 37 percent. Even though there is a rather large difference between the external and the internal rates of return, both are based on the same data and assumptions and are but alternative ways of expressing the same flow of costs and benefits. For further discussion of the internal and external rate of return calculations see Willis L. Peterson (1971).

10/ Lindner and Jarrett (1978) point out that the assumption of a convergent or parallel shift in the supply curve will result in overestimation of the rate of return if, in fact, the shift is divergent. Conversely, assumptions of a divergent shift will result in underestimation of the rate of return if the shift is actually parallel or convergent.

11/ This criticism and several of the others reported in this paragraph were aired rather thoroughly at a 1975 Airlie House conference. Webster and Ulbricht were particularly vigorous in their discussion of the limitations of the earlier studies. See the report of the discussion in the summary paper by Thomas M. Arndt and Vernon W. Ruttan (1977).

12/ For a test of the induced innovation hypothesis against the history of technical change in United States and Japanese agriculture see Yujiro Hayami and Vernon Ruttan (1971).

13/ There has been some disagreement about the magnitude of the spillover effects. See Robert Latimer and Don Paarlberg (1965); Dana G. Dalrymple (1965); Robert E. Evenson (1977); Robert E. Evenson and Hans P. Binswanger (1978); and W. E. Huffman and J. A. Miranowski (1978). The term <u>supporting research</u> is used to refer to basic research which is motivated to develop new knowledge in areas where the probability is great that the results will become a direct input into applied research. Examples of supporting research in agriculture are research on the biology and chemistry of nitrogen fixation or on the respiration of economic plants.

14/ See, Committee on Research Advisory to the U.S. Department of Agriculture (1972). The study was directed by Dean G. S. Pound of the University of Wisconsin.

15/ Annual data on the sources of funds available to state agricultural experiment stations have been published annually by the Cooperative State Research Service (1975).

16/ In the United States the short-run price elasticity of demand for domestically consumed food at the farm level is approximately -0.10 and for exports approximately -1.0. Since approximately 20 percent of U.S. farm output is exported the overall elasticity of demand is in the neighborhood of -0.25 (White and Havlicek, 1978).

17/ This is consistent with Hirschleifer's (1971) point that the possibility of distributional gains may induce individuals to combine rationally, through governmental or other instruments, to generate public information.

18/ For earlier analysis of factors affecting the funds available for agricultural research among states and among commodities, factors, and disciplines, see Earl O. Heady (1961, 1962) and Dana G. Dalrymple (1962).

19/ The constraints on group mobilization identified by Olson (1965) are particularly relevant to the issue of mobilizing consumers in support of agricultural research. "First, the larger the group, the smaller the fraction of the total group benefit that any person acting in the group interest receives. . . . Second, . . . the larger the group . . . the less likelihood that any small subset of members . . . will gain enough from getting the collective good to bear the burden of providing even a small amount of it. . . . Third, the larger the number of members of the group, the greater the organization costs and thus the higher the hurdle that must be jumped before any of the collective good at all can be obtained" (p. 48).

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