PRODUCTIVITY GROWTH IN U.S. AGRICULTURE: AN HISTORICAL PERSPECTIVE ON CAUSES, CONSEQUENCES, AND PROSPECTS

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Changes in the efficiency with which food and fiber products are produced on U.S. farms have been of substantial importance over the past century. Over a long span of time the American agriculture sector has realized productivity gains at a rate which is at least as high as that realized in the non-agricultural economy. American consumers and foreign consumers as well have benefitted from lower food prices made possible by these productivity gains.

The agricultural sector also has contributed importantly to export earnings over the decades. The incomes of American farmers and the earnings of farm labor and returns to land also have been affected, not always positively, by productivity growth.

The productivity slowdown in the general economy has prompted discussion about the prospects for continued productivity growth. This paper is intended to be part of that discussion. In order to provide more than a simple extrapolation of past trends, however, we require some understanding of the forces which influence productivity growth.

In the following section of the paper I begin by providing a summary of available measures of productivity growth in U.S. agriculture. I then discuss the implications of studies of the effects of public sector investment in research, extension, and schooling on productivity change. We do have considerable evidence that these investments influence productivity growth. We are then pressed, in turn, to ask what factors influence public investments in these activities and what are the prospects for their continued influence? A final section offers some suggestions for future prospects.

Productivity Growth and Its Correlates: A Descriptive Summary

We will begin our treatment with a descriptive summary of productivity growth in the agricultural and non-agricultural sectors of the economy.

Land productivity, or yield per acre, has long been used as an indicator of productivity efficiency in agriculture. It is useful for certain comparisons, but in general it provides an incomplete and biased measure of efficiency change. Yields can be increased, for example, by application of fertilizer, labor, and other inputs. Actually it is possible for efficiency to fall because too much fertilizer was applied, yet yields may increase.

Labor productivity, or output per unit of labor, is widely used as an indicator of efficiency in the general economy, but it is a very poor indicator of change in agriculture. Not only is it a partial or incomplete measure, as is land productivity, but it is affected by long-term labor market adjustment processes as labor migrates from the agricultural sector to non-agricultural sectors.

The index of output per unit of all inputs is generally known as a total factor productivity index and is designed to correct for the incomplete or partial nature of the other two measures. Ideally it should be measuring the change in the average cost of producing a unit of agricultural output at constant input prices. There are certain difficulties in calculating such indexes adequately, however.

I have utilized a "Divisia" index number approximation in calculating this index. The input index includes only the conventional inputs which farmers purchase on the market. The influence of public sector investments in research and extension, in the schooling of farmers or in roads and other forms of infrastructure are thus not accounted for by this measure. (In a later section I will report on analysis of the effect of these factors).

In spite of possible measurement problems, the total factor productivity index is the more meaningful of the measures, even though they are highly correlated.

There are certain cycles in productivity change. The 1910 to 1925 period exhibits little or no change. The mid 1930s, the late 1940s, and the late 1960s are periods of relatively slow growth, while the late '30s, the 1950s, and the late 1970s are periods of more rapid growth.

A comparison of agricultural and non-agricultural productivity growth over the post World War II period indicates that the agricultural sector tends to follow an independent cycle. The productivity slowdown of the past few years is concentrated in the non-agricultural and non-manufacturing sectors.

State and regional productivity changes (computed from Evenson 1978) from 1949 to 1971 indicate that the Delta region showed the most rapid improvement in productivity over this period with the Northern Plains, Southern Plains, and Southeastern regions also doing relatively well. This pattern reflects considerable catching up behavior. In a previous study, which measured productivity in the relatively rapid change period of the 1930s, change was most rapid in the Pacific and North Central regions and least rapid in the Southern States.

Since 1967-69, USDA data (Statistical Bulletin 233) show that the Pacific region has had the most rapid productivity change among USDA regions reflecting its tendency to lead other regions during periods of general increase in productivity. It has, in fact, been the leading region in terms of having the most rapid growth early in the 1930s cycle, the 1950s cycle and what might be termed the 1970s cycle. The Delta region ranks second along with the Lake States in productivity growth since 1969.

Determinants of Productivity Change

Fifteen years ago there was considerable debate over not only the procedures for measuring productivity change, but over the interpretation of these measures. This debate reflected the fact that we did not understand general processes of economic growth very well. Indeed many economists argued then (and would continue to argue) that total factor productivity measures were basically uninterpretable. Technical change was often treated as being produced or created by forces exogenous to the economic units under study. Very little attention was paid to the enterprises which produce and modify technology.

The situation is somewhat modified today, although a large part of the economics profession continues to have a rather poor understanding of economic growth. The agricultural sector has lent itself particularly well to studies of technology production and its effect on productivity growth. This is so because much of the research and inventive effort directed toward crop and livestock improvement is organized in the public sector. We have good data on agricultural research and extension resources employed in public in the U.S.D.A. and State Experiment Stations and in federal and state extension services. It has been possible with these data to undertake quantitative studies of the relationship between investments in research and extension and productivity change. These studies would not have been possible in other sectors of the economy.

We now have a considerable literature dealing with agricultural research and productivity. A recent survey by Norton and Davis (1980) cites more than 150 studies, most of which have been conducted in the past 15 years.

Several procedures have been utilized to estimate the contribution to increased agricultural productivity made by agricultural research. Table 1 provides a summary of a number of these studies of agricultural research productivity undertaken in recent years. This summary indicates that almost all of the studies have reported very high returns on the investment undertaken. The "internal" rate of return

Table 1. Summary of 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
Hayama & 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
Evenson & Jha, 1973	India	Aggregate	1953-71	40
Kahlon, Bal, Saxena & Jha, 1977	India	Aggregate	1960/61-	63

(Continued)

Table 1. Continued

Study	Country	Commodity	Time period	Annual internal rate of return %
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.

Source: Evenson, Waggoner & Ruttan, 1979.

estimates are generally well above the 10 to 15 percent realized on more typical investments in both the private and public sector. The pattern of high rates of return extends across different commodity oriented programs and across countries as well.

The studies classified as index number studies utilize an estimate of increased production as a measure of the annual benefits stream associated with the research program. A series of research and related costs or investment is also computed. The internal rate of return is then computed as the actual return realized on the investment. (An assumption that both the benefits and costs will continue to be realized in periods after the period of calculation is typically made.) It can be interpreted as the average rate of return realized over the time period of the study.

The production function studies rely on a quite different methodology. They are basically statistical decompositions of total productivity measures. Total productivity measures are rates of change in production which are not attributable to the contribution of conventional inputs under the presumption of constant technology. Since research programs do produce new technology if successful, they contribute to the growth in total factor productivity.

The production function studies specify a statistical relationship between productivity growth and research stocks. Research stock variables are defined to reflect the time lag between investment in research and the realization of the results of research. They also reflect geographic pervasiveness in that productivity in a given region (e.g. a state) is produced not only by research conducted in the region but in other regions as well.

The production function studies provide stronger evidence that agricultural research is in fact productive because a statistical test is employed. If agricultural research were not productive, no significant relationship between research variables and productivity change would be observed. With one exception, the studies cited in Table 1 have shown that research investment is significantly related to productivity growth. Given these estimates, the added production associated with an increment to the research stock can be computed and from this a rate of return to the incremental investment can be computed. These estimates are thus for marginal or incremental investments. They differ from the average rates of return reported in the index number type studies.

A more recent productivity decomposition study for U.S. agriculture (Evenson, 1978) is somewhat more detailed in several respects than those cited in Table 1. The study analyzed determinants of productivity change in U.S. agriculture for three historical periods; 1868-1926, 1927-1950 and 1948-1971. Estimates of the "time-shape" and the geographic pervasiveness of the research impact were obtained. In addition, the study estimated the contribution of the schooling of farm operators and agricultural extension investment to productivity.

Two types of agricultural research were defined. The first type was technology-oriented research, defined as research where new agricultural technology was the primary objective of the research. This included work in plant breeding, agronomy, animal production, engineering, and farm management. The second type was science-oriented research where the primary objective of the research was not to produce new technology but rather to investigate scientific questions related to the production of new agricultural technology.

Science-oriented agriculture research included phytopathology, soil science, botany, zoology, genetics, and plant and animal physiology research conducted in the Experiment Stations. The institutional setting in which it is conducted achieves a relationship between scientific research and technological research that is generally not achieved in alternative settings. Many scientific research organizations not only do not organize research programs in such a way as to respond to the interests and demands of the technology-oriented researchers but are openly hostile and antagonistic toward them.

Table 2 reports information about the stream of benefits associated with a $1,000 increment to investment in agricultural research and extension. For example, an investment of $1,000 in technology-oriented research in the Western states in the 1948 to '71 period according to this estimate would have generated a stream of benefits which reached a maximum of $12,200. These benefits would have begun in the second year after the investment and risen (linearly) for 7 years. They would then have remained constant for 8 years, after which they would have declined to zero again over a period of 15 years.

This investment would have yielded a handsome rate of return of 95 percent. It is also estimated that 67 percent of the technology produced would have been realized in the state initiating the investment. The remainder would have been realized by producers in other states. In general, crops research is pervasive across geo-climate sub-regions, while livestock research is pervasive across geo-climate regions. (Evenson and Welch, 1978).

These estimates reinforce the conclusions of the earlier studies summarized in Table 1. They show that the agricultural research system has been quite productive over the whole of its history. They further show that science-oriented research has been as productive as technology-oriented research. Note that these estimates apply to the aggregate of research projects undertaken in the experiment stations and do not imply that all individual research projects have been successful and productive.

Table 2. Estimated Effects of $1,000 Investments in U.S. Agriculture Research and Extension

	Maximum Level of Benefits	Time Shape Weights			Internal Rate of Return	Proportion Appropriated by State's Production
		Increasing	Constant	Decreasing		
1868-1926						
All Agricultural Research	$12,500	15	0	25	65	not estimated
1927-1950						
Agricultural Research						
Technology-oriented	11,400	5	6	11	95	.55
Science-oriented	53,000	15	20	25	110	.33
1948-71						
Agricultural Research						
Technology-oriented						
South	21,000	5	6	11	130	.67
North	11,600	7	8	15	93	.43
West	12,200	7	8	15	95	.67
Science-oriented	4,500	15	20	25	45	.32
Farm Management and Agricultural Extension	2,173	—	—	—	110	1.00

The estimation procedure has limitations. One major limitation is that the research and development activities of private firms supplying inputs to the sector is only indirectly taken into account. Implicitly, this and other studies assume that improvements in farm inputs produced by private firms are fully reflected in the prices paid for them.

They are actually only partially reflected in higher input prices and, to the extent that the difference between actual and full reflection is correlated with public sector research variables, some part of the benefits attributed to public research is actually due to private research. This possible bias is not sufficiently large to change the conclusion that returns to research have been extraordinarily high.

It should also be noted that some contributions of public sector research are realized through improvements in the inputs supplied by the private sector. The public sector experiment stations produce genetic material, chemicals, pharmaceuticals and other forms of technology which lower private industry costs of input production.

These studies of agricultural productivity growth have not fully explained or accounted for all sources of productivity growth. However, the reliability of the statistical estimates is sufficient to support the following summary propositions.

1) Productivity growth is closely associated with investment in agricultural research, and some part of the recent slowdown in productivity growth is therefore attributable to the decrease in agricultural research intensity in recent years.

2) The research contribution is part of the larger contribution of an integrated system of extension services, technology-oriented research, and science-oriented research. The statistical results support the proposition that science-oriented research improves the productivity of technology-oriented research (and vice-versa) and that technology-oriented research improves the productivity of extension and schooling activity.

3) The high rates of return to investment in research indicate that too little investment is being undertaken from a social perspective. A more optimal program of public sector investment would call for added investment which would lead to lower marginal rates of return (because of the law of diminishing returns which holds for research as well as for other forms of production), in line with returns realized on other forms of investment.

4) The high rates of return indicate that the present research system is probably quite efficient. It is quite possible for an inefficient and poorly managed research system to yield high rates of return, however. Many research programs in developing countries have high rates of return primarily because they have very low research intensities. So little research is being undertaken relative to

the potential value of new crop and animal production technology that even poorly managed systems yield high returns.

Distributional Consequences: The Basis for Political Support

The studies summarized in the previous section show that productivity growth is influenced by research and extension programs. Furthermore, the transferability of research results from one region to another is quite clearly impeded by differences in soil and climate factors and possibly in economic conditions as well. Most spillover of technology from one state to another appears to be confined to the similar sub-regions for crops and the similar regions for animal production.

We also know that the State Experiment Stations have a strong state political base, while research and extension are not given high priority at the federal level. Further, producers rather than consumers form the interest groups supporting these activities. Given the importance of these activities in determining productivity growth, it is also important that we have a better idea of their political support base. To that end I find it useful to first engage in some moderately technical analysis of the gains and losses associated with new agricultural technology. I then turn to a discussion of political interests.

The Analytics of Distributional Effects: Basically, research and extension programs can have a number of possible effects.

(a) Research produces new technology. Extension facilitates its adoption and encourages further development of minor technological improvements and managerial technology. This technology can be

(i) factor biased (i.e., labor using, etc.)

(ii) scale biased (i.e., more profitable for large farms)

(iii) region biased (i.e., not equally available to all farmers in different regions)

(b) Research and extension may change the demand for farm products (i.e., introduce new products, encourage consumption via nutrition education, etc.)

(c) Research, especially private research and extension, may lower the cost of purchased inputs (i.e., fertilizer, etc.)

(d) Research, but particularly extension, may lower the cost of labor mobility between regions and sectors of the economy.

From these possible effects, we can focus the general question regarding the overall effects of agricultural research and extension on the distribution of incomes on four more particular issues:

(a) the effects of agricultural research and extension on the distribution of incomes between consumers and producers;

(b) the effects of agricultural research and extension on the distribution of income among agricultural factors of production;

(c) the regional income effects of agricultural research and extension services;

(d) the impact of agricultural research and extension on the distribution of income among different sized farms.

Agricultural research and extension, insofar as it results in any rightward shift in the agricultural output supply function, leads to consumer gains (lower agricultural output prices) as long as the demand function for agricultural goods is downward sloping.

In this simple model, the final distribution of consumer gains among all consumers (and producers insofar as they too are consumers) would depend on their expenditure patterns. Consumers who spend a high proportion of their budgets on agricultural products will benefit proportionally more from a decrease in food prices. It is important to bear this in mind because the poor generally do spend the highest proportion of their budgets on food. Agricultural research and extension thus create a progressive (i.e., more egalitarian) distributional effect for that proportion of benefits passed on to consumers in the form of lower agricultural output prices.

The second dimension of the distribution question regarding the distribution among factors of production has been the subject of a few substantial pieces of theoretical work, for instance, Evenson and Welch (1974), Evenson (1980) and Binswanger (1980).

The simplest case of this distributional dimension is where there are only unsubstitutable factors of production, say land and labor. For given technology and a given demand function for agricultural output, as the price of land relative to the price of labor decreases, more land services will be demanded.

Agricultural research and extension, insofar as they result in technical change, will shift these demand curves for land and for labor. If the resultant technical change is neutral and demand is elastic the two factor demand curves will shift outward equiproportionately. This results from two forces. Technical change reduces the demand for *factors per unit of* output but because the output supply curve shifted downward, total output increased. Thus, the supply conditions of the factors are important in determining the division of the added producer revenue (price times quantity) between the two factors.

Because land is in relatively inelastic supply, its price rises relatively more than does the price of labor which is in relatively elastic supply. When final demand is elastic, the factor with the most inelastic supply is the biggest gainer. When final demand is inelastic the factor with the most inelastic supply is the biggest loser.

If technology were non-neutral, it would shift the demand curves in a non-proportional way. Suppose it to be labor saving. Then the shift in the demand curves will work to the disadvantage of labor and to the advantage of land. This analysis can be extended to the two region case in which we suppose that output is freely traded, though both land and labor are immobile between the two regions. This would then shed some light on the third dimension of the distribution question.

Analysis shows that technical change in region 2 lowers both costs and product prices for region 2 farms. However, since only output is mobile between regions, only region 1 product prices will decline. This imposes losses on the two factors in region 1 and these losses are determined by the supply conditions of the two factors in region 1, the rate, but not the bias, of technical change in region 2 and the share of region 1 in the total production of the 2 groups. If region 1 is a small part of the total and demand is inelastic the effect on region 1 can be drastic.

For region 2 the demand curves shift outward for neutral technical change. Landowners gain most because land is in relatively inelastic supply. With labor saving technical change their gains are accentuated. For land saving technical change, the reverse is true.

It is not surprising then that the owners of agricultural land rather than the owners of labor services have the strongest interests in supporting both research and extension. This becomes even more apparent if we relax the assumption of immobility of labor between the regions. If labor is perfectly mobile, group wage differences cannot exist and the wage will rise or fall in both regions by the same proportion, (predicted by the one region model). This will accentuate the losses by landowners in region 1 and the gains by landowners in region 2.

Agricultural extension which effects some transfer of the region 2 technology to region 1 producers will reduce the losses of region 1 landowners and the gains of region 2 landowners. If labor is immobile it will do this for labor as well. If extension increases the mobility of labor between the two regions, it will produce a more equitable distribution of wage payments but will exacerbate the gains and losses to landowners. We would accordingly expect all landowners in lagging regions (with low wages) to pressure extension services to transfer technology and to inhibit or at least not encourage labor mobility. Landowners in leading (high wage) regions will have an interest in seeing that labor mobility is encouraged and will tend to stress implementing state-produced technology as opposed in achieving transfer from other states.

Political Interests: This combination of interest goes a long way toward explaining our current research and extension system. We have state experiment stations supported heavily by state rather than federal funds and pressured to produce state targeted technology. The extension and research services seek to maximize adoption of technology and spillover across state boundaries. Sometimes this spillover takes place through "adaptive" research and invention in which, for example, a crop variety produced for one state is utilized as a parent variety in a breeding program in another state.

We would thus expect extension services, particularly those with a strong state staff integrated with the research program of the states to have the effect of lowering the differential gains and losses between geo-climate regions. The more investment made in state 1, the less the damage to producers surplus imposed by new technology suited to state 2.

Finally, the fourth dimension of the general distribution issue, i.e., the effects of research and extension on the distribution of income across different sized farms, is perhaps the most easily understood. It is clear why new technology is often differentially accessible to different groups of farmers. Within the same regions, large farmers have more incentives to search and to experiment than small farmers since the benefits from research are proportional to farm size while the costs are not. This naturally leads to early adoption of new technology by large farms, providing them with innovators' rent. These innovators' rent to large farms may be transitory unless new technology itself has a scale bias, i.e., the new technology reduces costs for large scale farms much more than for smaller ones, or unless input and credit markets remain accessible only to large farms.

Insofar as innovators' rents are temporary in nature, these rents ought not to be necessarily eliminated. These rents provide incentive for large farmers to perform experiments in a given year. This only lowers the cost of learning and experimenting for the smaller scale producers who would have access to and benefit from them in the immediate future.

In the case where innovation rents tend to be more permanent, institutional changes that facilitate access to new technology become necessary. Agricultural extension services then become an important feature of any institutional package designed to eliminate the permanent nature of some innovators' rents. Extension activities lower the cost of learning and experimenting and thus lower the levels of innovators' rents. Reducing rents to innovativeness via extension does not necessarily produce too little innovative activity since extension can also reduce the real cost of innovativeness. Again, however, the payoff to such activities depends on the capacity of small scale farmers to process and use new and cheaper information to their advantage.

Prospects for Future Productivity Growth

The earlier sections of this paper have been directed to (1) providing comparative measures of productivity performance, (2) reviewing the studies of the effect of research and extension investment on productivity, and (3) analyzing the economic interests of groups supporting agricultural research.

In this final section I will address two questions regarding future research and extension activity and relating these to future productivity growth. The two questions are: (1) Will the agricultural research and extension service continue to be supported? (2) Will this system continue to be productive?

The first question requires attention to changes in the size and power of the interest groups supporting agricultural research. I noted earlier that consumer groups have not been a significant interest group supporting research and extension. Indeed, the "consumerism" of recent years has often been antagonistic toward research. It has been particularly critical of real and potential collaboration with private firms who are generally seen as the "enemy". It has concentrated on food additives, regulation, and related issues rather than the price of food. I see no reason to suppose that consumer interest groups in the next few years will become a significant force supporting research to lower food costs. They will support some research on health, nutrition, and related matters, however.

It has also generally been the case in recent years that political expression at the federal level has not been a key factor in research and extension support. Indeed, recent federal administrations have attempted to inhibit research. OMB has questioned its effectiveness in recent years. This partly reflects the fact that at the federal level some producer groups see agricultural research as harming their real interests. I would think that this perception has probably changed and will continue to change as the agricultural economy becomes more export oriented.

There is little doubt that the productivity and export performance of the agricultural economy has been a bright spot in the general economic picture of the past 8 years or so. Furthermore, with strong export demand and rapid productivity growth, farm incomes and returns to factors have grown. As even a cursory glance at the data will show that landowners have reaped huge gains from the situation. We now have an incredibly wealthy agricultural sector.

One wonders whether the traditional political support for farm programs has not shifted in recent years with the rapid growth of large scale corporation farming and the growth in wealth of commercial farmers. Can one seriously use arguments about rural virtues, clean air, etc. to tax the middle class to protect the wealth of one of the economy's wealthiest sectors? I suppose we will continue to hear about the virtues of rural life for decades to come, but it seems to me that the real political support for farmers is based on pure interest group politics which farm groups perform very effectively, particularly in forming coalitions with agriculturally related businesses.

The growth of agricultural firms and private agriculture supply firms has not only affected the farm economy and its politics. It has also induced a change in the relative balance of research and extension activities. With the growth in private plant breeding in recent years and the increasing importance of farm chemicals and animal health products, the role of the public research and extension system is changing. Less attention is being given to main line production improvement and more to maintenance and regulatory problems. The case can be made in many areas of research and extension support that less public research be done.

The state level public support base has been the mainstay of the public system for many years and will probably continue to be. This, however, is mainly a producer interest group support base and it may be eroded by the increasing role of the private firm sector in some states. However, with responsiveness on the part of the system, the increasing agribusiness interests may actually result in an expansion of the system as the California system demonstrates.

This brings me to the second question regarding the future effectiveness of the system. It is related to the clientele structure of the system. Over the course of the last century, the agricultural research and extension system has gone through a number of reforms and institutional restructuring. It could not have remained productive had it not done so. Some of these reforms and changes were responses to the changing demand for the products of the system, some to the changing supply of fundamental scientific knowledge which was of relevance to the system.

It is important that any institution be responsive to both of these factors and that it remain true to its mission. The agricultural research and extension system has a real clientele represented by the interest groups supporting it. They not only influence funding, but in more critical ways articulate a demand for new techniques and solutions to problems in the system. The extension system plays a role in this articulation process. It is also important that there is a kind of competition among different state systems which induces more effective research.

In general, a research-extension system without effective clientele pressure, cannot be expected to continue to produce the most valuable and useful results. If it serves the interests of its own staff it will generally become unproductive. On the other hand, a research system cannot ignore its supply side. It must be capable of using all available and relevant scientific knowledge. Applied research organizations which cut themselves off from the larger scientific community quickly exhaust their discovery potential. This potential must be replenished and developed if the system is to remain productive.

As I look at the contemporary agricultural research and extension system, it seems to me that it is likely to prosper if it can convince state producer groups that it is servicing them well. I would judge that the responsiveness to the demand side is pretty high, and I would think that many state systems will be able to expand along the lines of the California model. This will necessarily raise the related political issues of public support for private groups, etc., which have also emerged in California.

I am not quite as optimistic that the system is maintaining its supply side and much is happening on the supply side. The modern developments in the biological sciences have relevance to agriculture. No research system can afford to give fundamental science low priority. Yet many experiment stations have an age distribution problem because of the slowdown in hiring in recent years. Many departments are stuck with an aging and obsolete faculty.

Fortunately, if some stations can realize some growth in staffing, this will probably bring in some younger scholars who will, by the nature of reasonably good graduate training, be bringing in new ideas.

In summary then, I don't see any serious erosion in the support level for agricultural research, or in its effectiveness. I would think that there is some prospect for some growth in both dimensions. It follows then that I see continued contributions to productivity growth in agriculture from the public sector. I will not say much about other factors influencing agricultural growth. The studies of the contribution of the research and extension system suggest that only around 1/4 to 1/3 of actual productive growth can be attributed to the system. In my judgment, the actual contribution is higher than that, and I would expect the agricultural sector to continue its relatively good productivity record for sometime.

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