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THE ORGANIZATION AND PRODUCTIVITY OF THE FEDERAL - STATE RESEARCH SYSTEM IN THE UNITED STATES

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Willis L. Peterson and Joseph C. Fitzharris

The agricultural research system of the United States can be discussed under two broad headings. In part I, the organization of the federal - state system is discussed. We investigate how political and physical geography, and production and input trends in the agricultural sector influenced the search by better farmers for new inputs, techniques, and organizational forms. The origins of the federal system, and its structure are detailed. A view of the workings and structural complexities of the system is given by an examination of the agricultural research system of Minnesota. The origins of the state system, the resulting organizational structure, and the types of work done at the state level are reviewed.

Part II of the paper deals primarily with the productivity of the Federal - state research system. After briefly reviewing the relationship between agricultural research and farm productivity, we attempt to offer an explanation for the absence of productivity growth in U.S. agriculture until about forty years after the establishment of the federal - state system. Viewing agricultural research and extension as an investment, we then provide rough estimates of the marginal internal rate of return to this investment for specified periods from the 1930's to the 1980's. Finally, some evidence is presented which bears upon the question of whether or not there is an efficient allocation of public agricultural research in the United States.

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I. ORGANIZATION OF THE FEDERAL - STATE RESEARCH SYSTEM

The federal - state agricultural research system of the United States is organized as a decentralized, co-operative system. Agencies of both the federal and the state governments form the system. Without central control, the system attempts to allocate resources, solve pressing problems, produce new varieties of crops and livestock, and conduct basic agricultural research. Combining teaching, research, and extension activities in the same system, the diversity of direction and the conflict of demands could have, but did not, produce chaos and less efficient resource use. The agricultural research system has contributed to the increased productivity of American agriculture, and the increased quality of life, both for farmers, and for consumers.

The American research system reflects political dualism, geographic differentials, and historical accidents surrounding its origins. Reviewal of these factors, and of the development of the system may help to explain its successes, and also its failures.

The National Setting:

The agricultural research system of the United States originated from popular movements on the state and national levels, and functions in a national as well as state economies. Three major factors affected its origins and development: agricultural and political geography; production trends in the agricultural sector; and a common set of problems facing farmers.

Geography:

Geography can be considered in terms of soil and climate variations across space, and political divisions across space. Political considerations were more important in the forming of the system; soil and climate in the development of the system. The United States is composed of a number of states and territories: Puerto Rico, Guam, Hawaii, the Virgin Islands, and the Panama Canal Zone. Each state is, in theory, possessed of considerable autonomy or sovereignty. In the years before World War II, the states jealously guarded their political prerogatives and powers from encroachment by the federal government, yet looked to the federal government for financial assistance in a host of measures. Over time, political autonomy has decreased as the federal government has added to its functions by legislative enactment and default by the states.

The Morrill Land Grant College Act of 1862 and the Hatch Agricultural Experiment Station Act of 1887 both reflect this political dualism. The needed research and teaching institutions could not be provided by the federal government, because of the structure of the system.Because of the political geography, each state received funds for a college of agricultural and mechanical arts, and for an agricultural experiment station. This division of effort along state lines had a practical benefit which was not fully realized by the legislators when the acts were first passed.

Variations in physical geography across the United States are considerable. Thin, rocky soils in the Northeast made profitable farming difficult. In the South, excessive mistreatment of the soil, and continual cropping in tobacco and cotton led to leaching of nutrients and erosion. With the settlement of the Great Plains region, arid agricultural practices had to be developed and employed by the American farmer. West Coast agriculture embraced climatic variations that ranged from arid and "Mediterranean" to heavy rain extremes. No single research unit could begin to cover these broad differences. And, within each region, conditions of soil and climate varied considerable. The joint federal-state system, established primarily for political reasons, was justified by climatic and soil variations as well.

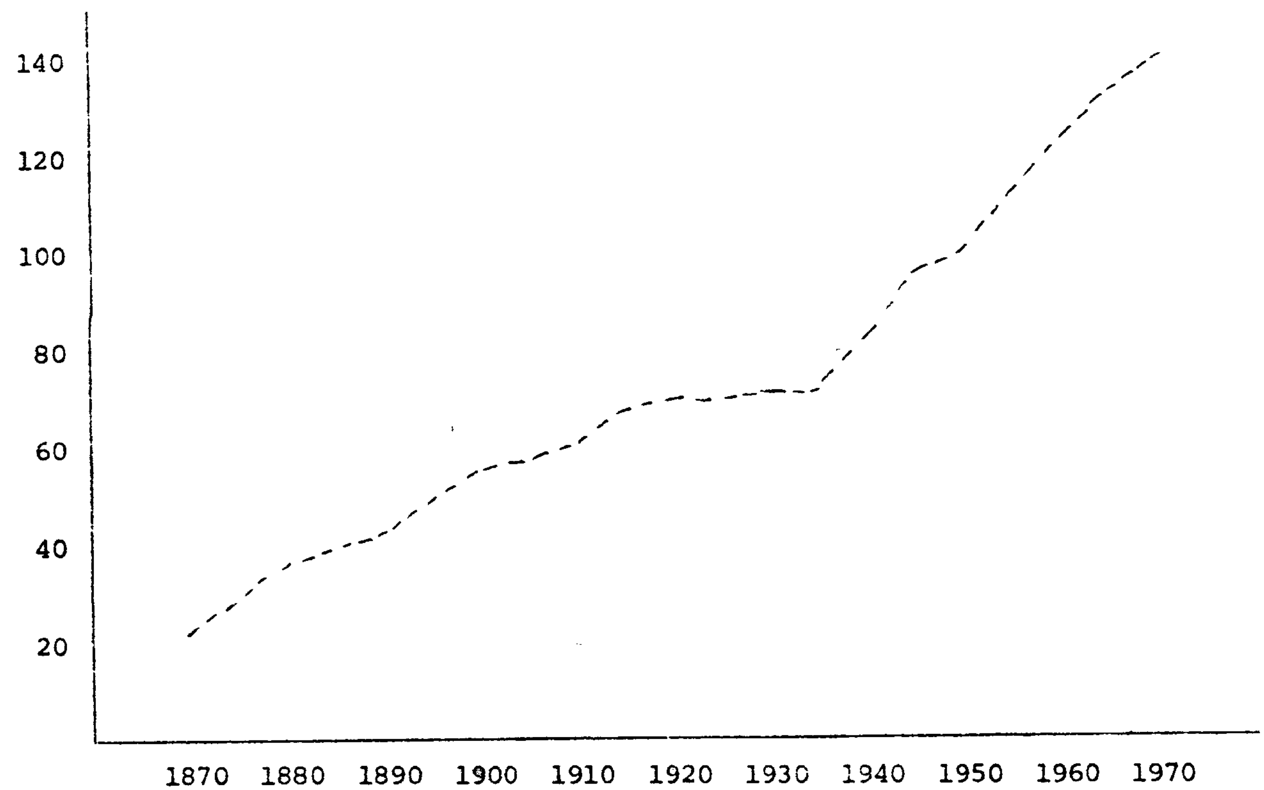
Production and Input Trends:

The index of farm output (figure 1) for the United States shows that, between 1870 and 1915, farm output tripled. Between 1915, and 1935, output remained roughly constant. Rapid growth in 1935-1945 was followed by a period (1945-1950) of slow growth. Since 1950, growth in farm output has been rapid.

Before 1915, the growth of farm output rises at about the same rate as that of improved acreage. Between 1915 and 1935, little new acreage was brought under cultivation, and much crop land was lost to urban sprawl. After 1935, land in farms decreased, as urbanization and suburbanization rapidly increased. After 1915, the very apparent relationship between the expansion of farm land and farm output growth disappears. During the 1915-1970 period, farm labor was

Figure 1:

Index of U.S. Farm Production, 1870 - 1970
(1947 - 1949 = 100)



Source: <u>Historical Statistics</u>, Series K-190, p. 288, and <u>Agricultural Statistics, 1972</u>, p. 537 (adjusted from a 1967 base). Decennial Observations, 1870-1910.

drastically reduced in members. Capital alone of the traditional factors of production expanded. (Appendix Tables 1-3)

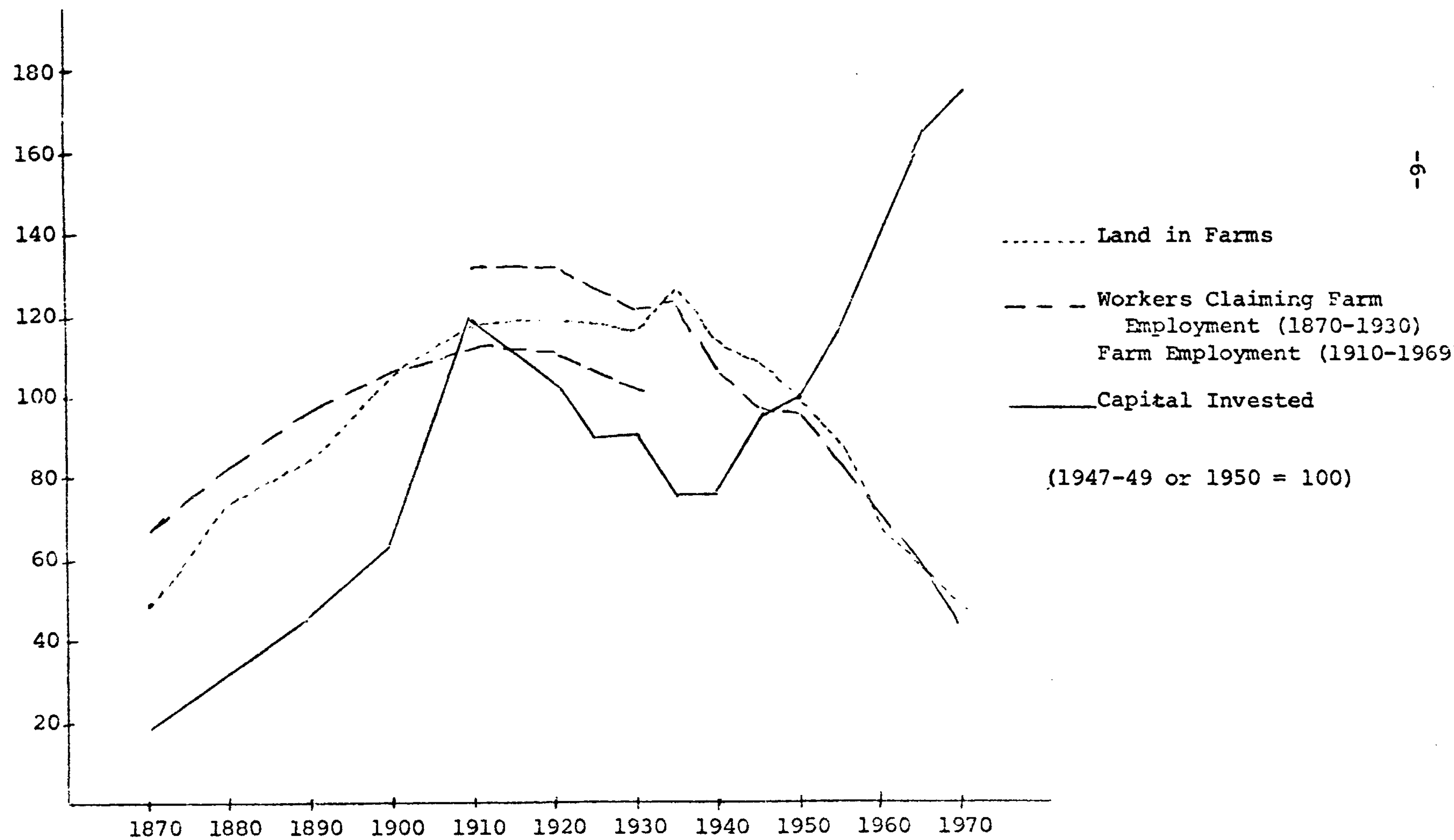
The rise in farm output to 1910 can be explained by the physical expansion of agriculture (in land, with farmers and capital also expanding). After 1910, physical expansion does not contribute to the expansion of output. Figure 2 illustrates the relationship between the expansion of land and labor and capital. After 1910, capital becomes increasingly large, except during the agricultural depression of the 1920's and 1930's. Clearly, capital (the value of land and buildings) does not account for machinery, fertilizer, new, disease-resistant strains of crops, and better livestock. Nor does capital include better farming practices.

Better farming practices alone tend, ceteris paribus, to increase output. Combining better farming methods with hardier and/or disease-resistant crop strains would further increase agricultural production. Improved health of livestock would also increase farm income or product. All of these resulted after 1880 from the work of the agricultural experiment stations. These stations worked with existing crops, using a trial selection process. After 1900, some basic research was done to find cures for various livestock diseases (e.g. hog cholera serum). The objective of this work was to maintain yields and production levels.

Common Problems:

Across the United States, agriculturalists faced a set of common problems. Among these were crop and livestock morbidities and mortalities, declines in soil fertility, and hardier crops suited to

Figure 2: Traditional Production Inputs (Land, Labor, Capital) U.S. Agriculture, 1870 - 1969



Source: Tables 1, 2, and 3.

greater temperature extremes and shorter growing seasons. Few of these problems could be solved by individual effort. Group effort, costly in money and time, was too much for the ordinary farmer - only the better farmers who could afford the financial burdens and the luxury of experimentation could support such effort. By the 1840's, better farmers in established agriculutral areas realized that the effort was beyond their capabilities. As newer regions matured, the better farmers in those regions imitated the experience of their eastern confreres, and tried group efforts. They too found their means limited and their objectives vast. (North, 1971)

Compounding the difficulties of group efforts were lack of information, and local or regional problems which often were hard to delineate. Information was exchanged in farm journals and personal correspondence, as well as transmitted by migration. The total impact of this exchange appears to have been limited to regions and states of origin. Very little interstate transmission between groups occurred. Local problems, such as crop adaptation to shorter growing seasons, or semi-arid or humid agriculture, frequently were unique. Little, if any, knowledge was formally transmitted to farmers in these areas. New methods and crop varieties and strains diffused slowly by imitation and trial and error. Because of these problems, and because of the difficulties of successful group efforts, the better farmers turned to their governments for assistance.

THE FEDERAL - STATE SYSTEM -- THE MACRO-LEVEL:

The federal - state agricultural research system developed in response to a variety of forces and factors operative in the American economy in the nineteenth century. Originating in legislative responses to the demands of farmers and their organizations, is still closely limited to farm groups. The structure of the system has been powerfully influenced by its origins, and leaves many confused. Americans think of their state stations as autonomous, but co-operating with other stations and the U.S.D.A.. Foreign observers frequently view the American system as a centralized, or centralizing inspite of provincialistic contrary tendencies (Knoblauch, 1962; Arron, pp. 5-18, frequently approaches this view). Similarly, the combination of teaching, research, and extension is viewed by foreigners as inefficient. (Arron, pp. 58-65.)

Origins and Early Development.

In the 1790's, shortly after independence was achieved, agricultural societies were formed in several of the states. These societies, formed by the better, wealthier farmers, encouraged their members to experiment, to collect new varieties of seeds and animals, and to spread this knowledge widely. To this end, the societies published the proceedings of their meetings, sponsored farm journals, and sponsored (and promoted the establishment of state) agricultural fairs. Private effort, both individual and in groups, was the thrust of their emphasis.

As private effort and initiative in agricultural research became increasingly costly, the problem of adequately supporting this research increased in difficulty. By the 1840's, the societies had turned to their state governments for assistance, and several states responded by establishing state departments of agriculture. These departments did not conduct research, serving instead as collectors and disseminators of knowledge. In this, they were assisted by the agricultural workers in the Patent Office in the United States Department of the Interior. During the 1840's and 1850's, agricultural groups began calling for a federal department of agriculture.

In 1862, the Congress authorized the establishment of the United States Department of Agriculture (U.S.D.A.) This federal department was not explicitly charged with conducting research, but the implications were clear. Also in 1862, the Congress passed the Morrill Land Grant College Act. This act provided for the allocation of public lands to the various states, to be used to support one or more state colleges of agricultural and mechanical arts. These colleges were encouraged to maintain experimental farms and to conduct adaptive trials of crops and shrubs and livestock. Intended to support their teaching function, these farms became useful to the colleges in helping them serve the farmers of their states who requested information about problems facing them.

Because of the small base of agricultural knowledge, inadequate to provide a solid academic curriculum in agricultural education, the colleges worked to extend the scientific knowledge of agriculture. By the 1870's, the inadequacy of the colleges of agriculture in extending the frontiers of knowledge and in solving agricultural problems had become apparent. The first agricultural experiment station was established in Connecticut in 1876. Several other states also established experiment stations, often separate from their colleges of agriculture. (Knoblauch, 1962; True, 1937)

In 1887, the Congress passed the Hatch Act which provided federal funds for the support of state agricultural experiment stations. In response to this act, the states authorized the establishment of stations attached to their colleges of agriculture. Unlike the German model at Moeckern, Saxony, the American agricultural experiment stations were and are attached to colleges of agriculture. Similarly, the agricultural extension services of the various states, established after the passage of the Smith-Lever act by the Congress in 1914, are also attached to the colleges. (Knoblauch, 1962; True, 1928)

Both in the first call for state departments of agriculture, in the movement for a federal department, in the allocation of federal lands to the states for the support of agricultural colleges, and then in the movement -- at the state and the federal levels -- for agricultural experiment stations, farmers and farmers' organizations played a central role. The better, wealthier farmers were instrumental in creating the movement for government assistance to the agricultural sector. These farmers and their organizations helped to create the institutional arrangements (Fitzharris, 197a; North, 1971) necessary to allow government aid. And, these better farmers and their organizations, having perceived the need for agricultural research, and having realized that private efforts were inadequate to the task, strove for government aid, and served as "watch dogs" over the system which they had helped create, criticizing, demanding, and protecting.

Structure:

Within this federal - state structure, the states have created research systems based on their colleges of agriculture. The teaching college forms the base of the system, with the research activities being carried out by the staff of the state agricultural experiment station attached to the college. Extension work is the responsibility of the state agricultural extension service which operates in the counties and is attached to the state agricultural college. On the federal level, the U.S.D.A. maintains a large staff or research workers, both in the national capital, and in laboratories, stations, and other federal installations across the country. Additional federal workers and facilities are stationed on the campuses of the various colleges of agriculture in the states. The states and the federal government co-operate closely in work on problems which cross state borders, or which are national in scope or origin. An example is Cereal Rust which involves federal and state cooperation both in the state and federal laboratories and stations in the United States, and at research units in northern Mexico, conducted in cooperation with the Ministry of Agriculture of the Republic of Mexico. (Stakman, 1967, 1973, 1974; Rowell, 1973)

The complexities of structure and authority can best be examined at the micro level. Examination of the agricultural research system in a state will elucidate the structure of the system, and bring out the lines of cooperation. The American system is bipartite, and the vast bulk of work is done on the state level by the various autonomous state agricultural experiment stations. The development of the Minnesota Agricultural Experiment Station and Institute of Agriculture in the University of Minnesota will serve as the case study of the micro level of the system.

THE MINNESOTA CASE -- THE MICRO LEVEL

In Minnesota, the first efforts to develop a college of agriculture (1858) were unsuccessful. In 1869, the second attempt began with the establishment of a college of agriculture in the University of Minnesota. The college lacked stability in the early years, with no students and a rapid turn-over in professors. In addition, its experimental farm was inadequate for experimental purposes, and poorly funded. A new campus and farm was acquired in 1882, and the Farmers' Lecture Courses, the fore-runner of the Agricultural Extension Service in Minnesota, was initiated. (Boss, 1935; Fitzharris, 1974a)

As a part of the movement to gain federal support for agricultural research, the Minnesota legislature authorized a state agricultural experiment station at the University. Established by the University Regents on the University Farm in 1885, The Minnesota station remained a paper creation until the passage of the Federal Hatch Act in 1887. After Hatch Act funds became available, the station hired a staff and began operation.

Agricultural extension work was initiated in 1910, and the Agricultural Extension Service established in 1914. Branch Stations were established in the years after 1893, to serve the diverse geographic sections of the state. Expansion of the college faculty-station staff was followed by the beginning of graduate training. As this system developed, many of the geographic and economic forces which affected the national system also affected the state system.

The State Setting:

The Minnesota agricultural research, extension, and education system developed out of local, state, and national movements for governmental aid to agriculture. Various farmers' organizations were instrumental in the origins and development of the Minnesota system. Soil differences, production trends, and problems too great for farmers and farmers' organizations to solve shaped the developing system of agricultural research in the state.

Geography:

Political geography within the state centers on the urban-rural differences. These differences, only partially geographic, have not seriously affected the development of the Minnesota Agricultural Experiment Station and Institute of Agriculture.

Soil and climate differences across the state are important factors. Considerable variation in growing season, climate, and average moisture exist between the various regions of Minnesota. Soil types and quality, which effected the types of farming vary across the state. Because of physical and climatic factors, branch stations located in the various major regions have been important components of the Minnesota agricultural research system.

Production and Input Trends:

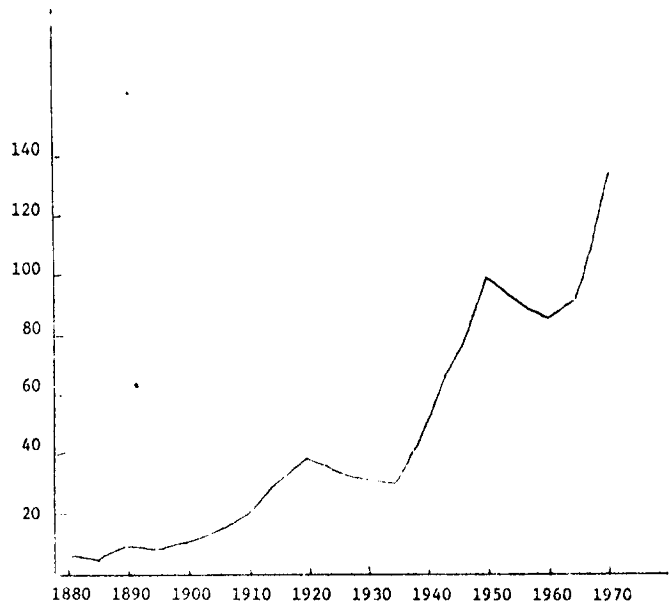
The value of agricultural production in Minnesota grew sevenfold between 1880 and 1920. During the 1920's, and the early 1930's, output declined slightly. After 1935, production again rose, tripling to 1950. A brief decline in the late 1950's and early 1960's interrupted an otherwise continual increase in the value of agricultural production (figure 3).

Between 1880 and 1930, farms doubled in number, and improved acreage tripled. Land in farms continued to expand to 1950, and improved acreage declined after 1950. The decline in improved acreage is twice as great as that of total land in farms. From 1940, the numbers of farms has declined, and labor employed (both paid and unpaid) in farming fell rapidly between 1940 and 1970. Aggregate capital inputs (in horsepower equivalents) is the only input which has risen over the entire period. (figures 4 and 5) (Fitzharris, 1974b)

Efforts by the Minnesota station to produce hardier crop varieties with shorter growing seasons resulted in increased land productivity between 1900 and 1920. In the 1930's, and again after 1950, land productivity rose as more fertilizers, pesticides, and better, disease resistant crops were utilized. With the exception of the 1890's and the decade of the Great Depression (the 1930's), labor productivity has risen. The expansion of land per worker has been uneven, varying with the adopting of new methods and machinery. The substitution of animal power, steam power, and the internal cumbustion engine/diesel engine tractors for human power explains much of the changes in land per worker. (figure 6)

FIGURE 3

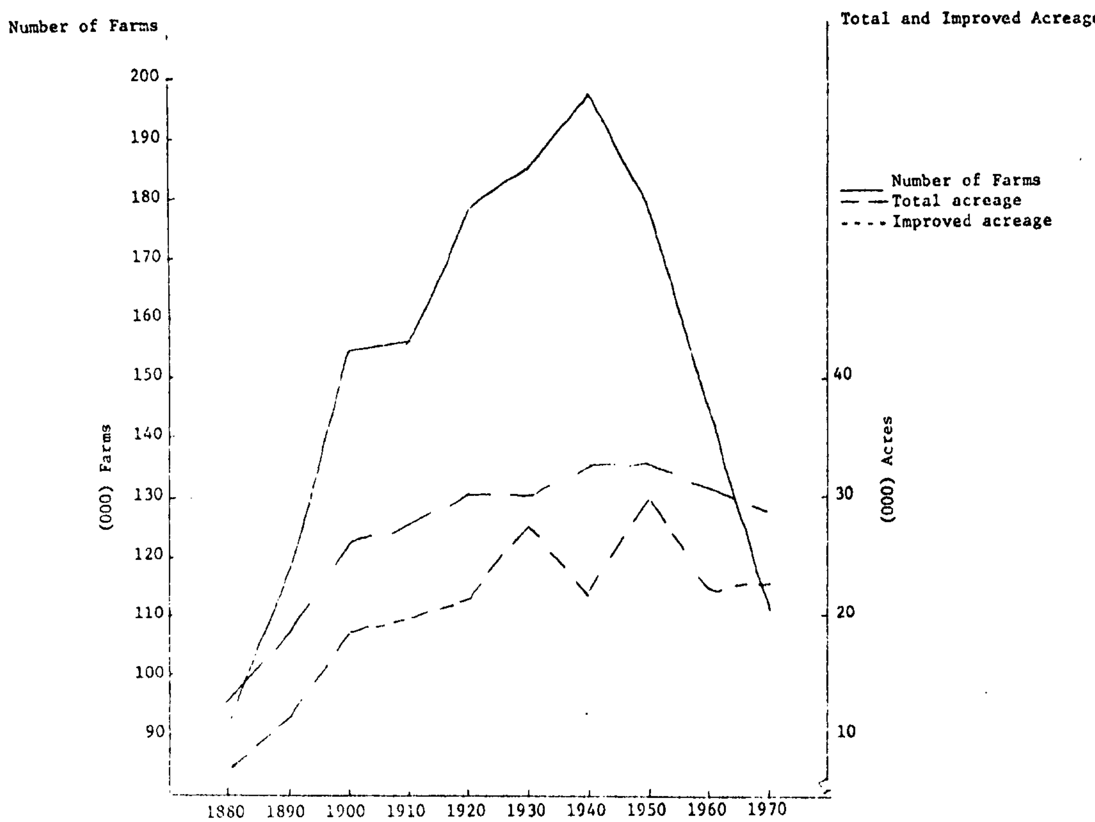
Index of the Value of Minnesota Agricultural Production, in constant 1950 dollars (1950 = 100)



Source: Fitzharris, 1974b.

Note: Observations are five year averages for every fith year.

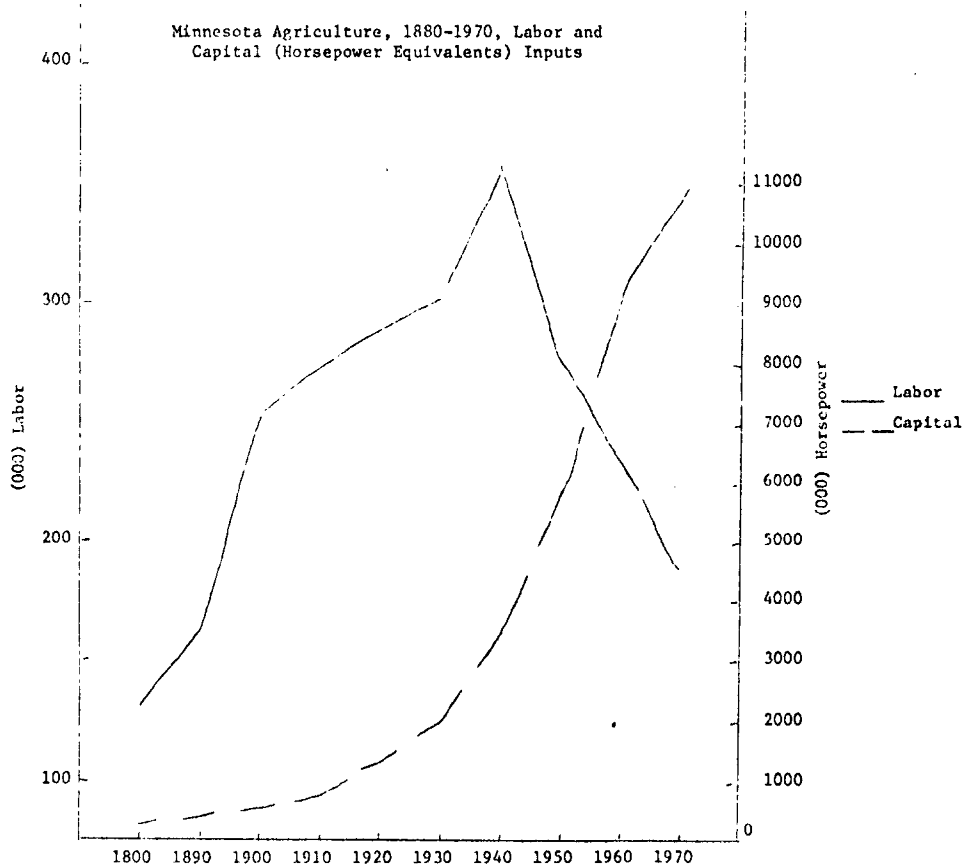
FIGURE 4



Source: U.S. Bureau of the Census, Census of Agriculture, 1880-1970.

FIGURE 5

Minnesota Agriculture, 1880-1970, Labor and Capital (Horsepower Equivalents) Inputs



Source: U.S. Bureau of the Census, Census of Agriculture, 1880-1970; Fitzharris, 1974b.

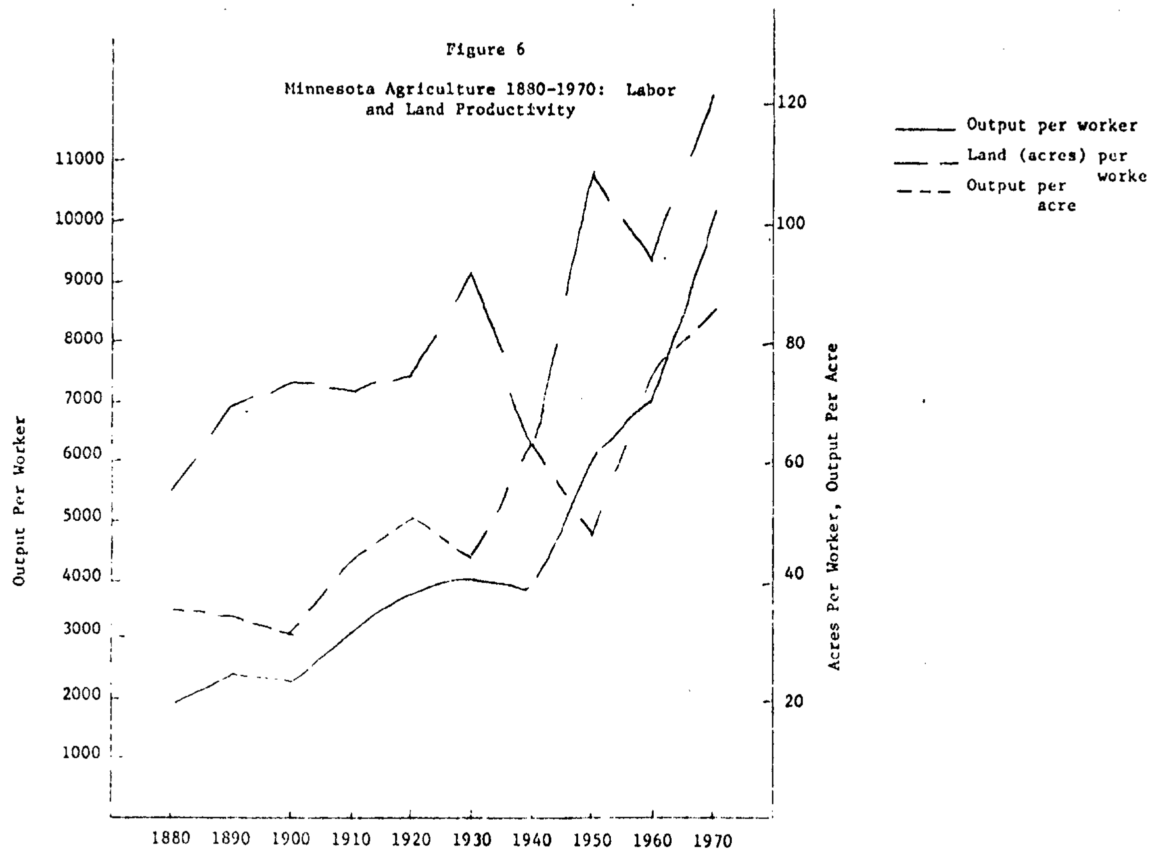


Figure 6

Minnesota Agriculture 1880-1970: Labor and Land Productivity

The Failure of Private Efforts:

The various farmers' organizations in Minnesota in the 1850-1890 period attempted to find solutions to many of the problems facing Minnesota farmers. Individual efforts were too costly, and group effort, because of the"free rider" problem, also failed. Realizing the limitations of individual and group efforts, these organizations turned to the state government in their search for assistance. Since state resources were clearly inadequate, particularly since Minnesota was a frontier society, these groups joined with organizations in other states in seeking federal assistance. (Boss, 1935; /Minnesota/State Agricultural Society, 1911)

From the lobbying and other promotional work of the various farm groups came the congressional and state legislation establishing the land grant colleges and their experimental farms. When these educational institutions were unable to meet the needs of the agricultural sector, farm groups and agricultural educators turned to the federal government and requested an experiment station system, following the Connecticut example. (Knoblauch, 1962; True, 1937) In Minnesota, the state government authorized an experiment station in 1885, two years before the federal Hatch Act was passed, but did not provide funding. Federal support was necessary for the development of the Minnesota and other state agricultural experiment stations. Without the pressures exerted by national farmers' organizations, and the impetus of the state groups, the experiment station system would have been considerable longer in coming, if at all.

In Minnesota, the farmers' groups were instrumental in the development of the agricultural experiment station. In the state election campaigns in the 1880's and 1890's the experiment station-college of agriculture objectives and accomplishments were frequent topics of political debate. These debates left the station and college administrators and the University Regents firmly convinced that the first duty of the agricultural research, teaching, and extension system was to serve the farm sector's immediate needs. Basic research was of lower priority in the early years. (Boss, 1935; Stakman, 1974; Fitzharris, 1974a)

Origins of the Minnesota System:

In 1881, Edwin D. Porter, the fourth professor of agriculture in the College of Agriculture arrived in the state. He realized that the support of farmers and legislators was essential to the role and mission of the College and its Farm. Porter met with the various farmers' organizations, with the leading citizens, and with the leading legislators, to determine their views on the role of the College and Farm in the service of the state. Obtaining a new campus and farm for the College was the first major accomplishment of the new professor. On the new University Farm, Porter built the foundations for the Minnesota agricultural research and teaching system. (Boss, 1935; Fitzharris, 1974a)

Beginning in the early years of the College and Station, the staff worked closely with the various farmers' organizations and commodity groups as they were founded. Frequently serving as the corresponding secretaries and officers, the staff gained closer contact with the farmers and their problems. Through the Schools of Agriculture, first founded on the St. Paul University Farm in 1887, the staff gained even closer contact with farmers and their problems, and also learned of the usefulness of their suggested solutions. These secondary schools, which at first depended on the station staff-college faculty for part of their teaching staff, were intended to train students to gain admission to college, to encourage the students to attend the college of agriculture, and also to train future farmers and community leaders. Begining in 1910, schools of agriculture were opened at most of the branch stations.

In 1882, a series of lectures, the Farmers' Lecture Courses, was established, following the example of colleges in other states. From this beginning, the Lecture Courses were gradually expanded, and renamed the Farmers' Institutes. Congress passed the Smith-Lever Act in 1914, providing federal support for agricultural extension work. The Agricultural Extension Division of the experiment station was separated as the Agricultural Extension Service. During the 1910-1917 period, the Farmers' Institutes were absorbed by the Agricultural Extension Division/Service. The Extension Service, by law was supervised by a farmers' organization, the Farm Bureau, in each county. These ties to one farmers' organization, particularly in years of conflict between the various farmers' groups, was deadening in its effect on the Minnesota Agricultural Extension Service (and on those of other states as well). Confidence in the Service was decreased, and many farmers believed that favoritism was shown to members of the Farm Bureau. In the 1950's the Service was formally separated from the Farm Bureaus, and fully funded by the state and federal governments, assisted by the counties in which agents were stationed. (Minnesota Agricultural Extension Service, 1936, 1957)

Structure:

The structure of the Minnesota Agricultural Experiment Station and Institute of Agriculture began with the organizational form adopted to meet the requirements of the Hatch Act in 1888. A Department (now the Institute) of Agriculture, was established to supervise both teaching and research activities. The Dean of the Department was also the Director of the Agricultural Experiment Station. An Associate Dean headed the College of Agriculture, and the School was headed by a Principal. Academic subject matter divisions were established in the Station and College, and the Station staff and College faculty were identical. (Hueg, 1973; Sloan, 1973; Boss, 1935; Minnesota Agricultural Experiment Station 1888-1964)

Following the establishment of the Agricultural Extension Service, the Director was co-equal with the station Vice-Director and the College Associate Dean. In 1952, the Institute of Agriculture was created out of the Department of Agriculture, and the Directorship of the Station was separated from the Institute Deanship. The College Deans and the Directors of the Experiment Station, the Agricultural Extension Service, and the Office of International Programs in Agriculture were co-equal. The College of Veterinary Medicine became an autonomous unit, cooperating with the experiment station in animal research.

Cooperative arrangements were made with various experiment stations in neighboring states (in the 1890's with the stations in North and South Dakota), and with the various agencies of the U.S.D.A. Several U.S.D.A. personnel were assigned to the Station and given academic rank in the College. After Professor Stakman began working as a cooperating federal agent in barberry eradication and cereal rust investigation, numerous federal plant pathologists were assigned to the University, and in the 1950's, the U.S.D.A. Cereal Rust Laboratory was established at the

University, cooperating with the Department of Plant Pathology. Farm management work in cooperation with the U.S.D.A. Bureau of Statistics in 1902. (Boss, 1935; Minnesota Agricultural Experiment Station)

Work Done at the Minnesota Station:

In the first years of the Minnesota Agricultural Experiment Station's existence, the staff centered their efforts on disseminating information produced by other stations, adapting that information to Minnesota's soil and climatic conditions. They also began working to develop varieties of crops and shrubs better suited to Minnesota agricultural conditions. Later, the station began crop and livestock breeding experiments, conducted research in farm management and agricultural engineering, and worked on plant morbidities and mortalities, especially cereal rusts.

Much of the work done in the early years was maintenance work, or "applied-developmental" research. Work on cereal rusts illustrates the differential. At first, barberry eradication programs were the major emphasis in the station's efforts to combat cereal rusts. Since the barberry plant harbors the wintering parasite, the fastest way to prevent cereal rust was to eradication of the wintering host. Later, as plant breeding work became more sophisticated, and as time permitted, disease resistant plants were developed. Eradication of the barberry had "bought" the station time to breed disease resistant strains. The national effort was relaxed in the late 1940's; and in the early 1950's, a serious outbreak of cereal rust destroyed much of Minnesota's wheat crops. Since that time, the breeding of disease resistant plants, in close co-operation with the various U.S.D.A. laboratories and field units, both in Puerto Rico, Mexico (where new strains of cereal rust are indentified), and in the United States, particularly the Cereal Rust Laboratory at the University, has been an unremitting effort. This problem, similar to that of blast, was solved through the joint efforts of state and federal researchers. (Stakman, 1967, 1973, 1974; Rowell, 1973; Wortman, 1972)

A leading and continuous line of work was crop adaptation. Efforts to move crops northward, adapting them to shorter growing seasons and colder climates began in the 1890's. The initial work involved trial experiments and the selection of the best varieties. Considerable success was achieved in moving corn northward, and in selecting wheat varieties better adapted to the shorter growing season of the northern two-thirds of the state. After the turn of the centruy, breeding and cross-breeding experiments were initiated. Breeding efforts were even more successful than trial experiments in producing varieties adapted to the rigors of climate and soil conditions in Minnesota. Much of this work has been cooperative, involving the neighboring state experiment stations, the Minnesota branch stations, and various bureaus in the U.S.D.A.. (Boss, 1935; Hays, 1963)

Analysis of station publications reveals that applied-developmental work in the first forty years of the station was closely associated with basic work on crops and livestock (feeding trials, breed and varietal adaptation work), and engineering work. Human and animal nutritional studies were especially prominent in the years before World War I. In the 1920's and 1930's, the transition towards basic-applied work was pronounced. The bulletin analysis reveals this trend inspite of the biased sources of data. (Fitzharris, 1974a)

Maintenance research conducted into the 1920's proved to be a very useful emphasis for the station. While not raising productivity in the agricultural sector, the station most likely prevented, or mitigated, declines in productivity due to crop and animal diseases. By conducting adaptation work, both for plants and for animals, the station produced strains and varieties which could be grown in Minnesota's colder climate and shorter growing season. Shelter-belt and drainage work both improved the soil and soil-retention of the farm. On balance, while the station did not produce many new discoveries, it did preserve the status quo.

In the 1920's, the station began moving heavily into basic-applied research. The long lead-time between initial investment in basic work and the beginnings of positive returns from the work help to account for the relatively constant productivity of the agricultural sector in Minnesota. Maintenance work continued, and in the late 1930's, the basic work began to pay-off in higher productivity in the agricultural sector. The dedication of the station staff, and their willingness to forego the honors and rewards accruing to basic research discoveries in favor of the less glamorous but necessary maintenance work during the first forty to fifty years of the station represent a sizable personal investment in the future of Minnesota's agricultural sector.

Summary of System Organization:

Several unique features and several implications for developing countries can be drawn from the evolution of the American federal --

state agricultural research system. The origins of this system are most important, both for the course of the system's development and for the acceptance by farmers of the work done by the system. Better, and wealthier, farmers realized that some form of research was needed to find remedies for the problems facing agriculture. Through individual and group efforts in the private sector, they moved to meet this need. Because of the high costs, the inability to confine the benefits to the funding groups, and the inability of even the better farmers to master both the farming skills and the scientific training necessary to maintain their farms and to do research, public efforts were the alternative of last resort. These farmers and their organizations turned to the public sector, their state and then the federal governments, for assistance. Instrumental in the formation of the system, farmers and farmers' organizations have guided the system in its development and in its research work. Because of their close relationships with the research system, the better farmers have served as models for the surrounding farmers, and have made possible faster acceptance of the work done by the agricultural research system.

Unique features:

The American agricultural research system is unique on several counts. First, the system was not created by government fiat in response to a government-perceived need, but rather in response to demands from the agricultural sector for state and federal assistance. Second, the system was established as a decentralized, co-operative federation of national and state institutions, each autonomous of but co-operating with the other institutions in the system. Third, the state institutions, except in the smallest states, include regional or branch experiment stations. Central control is coupled with decentralized initiative in the state systems. Fourth, the American system combines, frequently in the same people, the research, teaching, and extension specialist functions. Finally, personnel from the United States Department of Agriculture are often assigned to state institutions, with academic rank and prerogatives. U.S.D.A facilities are frequently located on the campuses of state institutions (*e.g.* the Cereal Rust Laboratory at the University of Minnesota).

Implications:

Implications for developing countries can be drawn from the state and the federal levels of the American system. On the federal level, problems which are common to the country (cereal rust) or to a multi-state region (*e.g.* cotton diseases) are the primary focus of effort. U.S.D.A. regional laboratories and specialized laboratories have been established to facilitate this effort, usually in cooperation with various state institutions. The result has been a specialization of effort geographically and by crop, which partially reflects the political division of the system. A political necessity worked to produce specialization of effort which promotes a more efficient use of resources.

From the state level of the system, several implications for hastening the adoption process and for the timing of work emphasis can be delineated. The support of the better farmers, and of the farmers' and commodity organizations is crucial to the system. Without this support, the system operates in a vacuum, without contact with the realities of farming. Agricultural training in secondary schools, such as Minnesota's Schools of Agriculture, provides a group of receptive future farmers and also produced some future agricultural researchers. In addition, this secondary schooling provides, as in the Minnesota case, a linkage between the station staff of researchers and the farmers whose children are in the school. The staff of the Minnesota Agricultural Experiment Station and College of Agriculture closely identified with the rural, agricultural sector of the state, and strove to better the standard of living and productivity of the people. Combining teaching, research, and extension specialist functions in the same people produced better teachers, researchers who were more aware of the problems and possibilities in agriculture, and extension specialists who were better equipped to help farmers. What could have been a liability was turned into a positive advantage, largely because the staff was interested in the people of the state. In the early years of the Minnesota station, maintenance work was the principle line of effort. Over time, the station turned to basic - applied research, while continuing maintenance work. The less glamorous and less noticeable (and less reputable) maintenance work is as important as the basic-applied work, and has been done by the principal researchers rather than assistants.

Summary (Part I):

The United States has developed a decentralized, co-operative federal - state agricultural research system. Within this system, problem solution and scarce resources are allocated in an effort to achieve maximum results at minimum cost. Specialization of effort and expertise has developed as the system strives to use its scarce human and financial resources efficiently. Through maintenance research, as well as basic-applied research, the system has produced considerable gains for the national and state agricultural sectors.

II. PRODUCTIVITY OF THE FEDERAL - STATE RESEARCH SYSTEM

A. AGRICULTURAL PRODUCTIVITY 1870-1972

It is helpful to think of research as a production activity with inputs of scientific man-years, laboratory facilities, etc. and output consisting of new knowledge. In order to gauge the productivity of research we need a measure of both its inputs and output. Although research inputs can be measured fairly easily, at least in monetary terms, the same is not true for the output. Fortunately research output can be measured indirectly by measuring the productivity of the industry at which the research is directed.

In the case of agricultural research, part of the output (new knowledge) is transmitted directly to farmers and part is utilized by experiment stations and farm suppliers as an intermediate input. In both situations the new knowledge makes possible the production of new or improved inputs for agriculture. To the extent that quality improvements in agricultural inputs are not fully and accurately measured, we <u>may</u> obtain an increase in total factor productivity in agriculture. Hence we may use the observed growth in agricultural productivity as a proxy or indirect measure of the output of agricultural research.

As shown in Figure 7, the major share of U.S. agricultural productivity growth over the past century has taken place since the mid 1930's. A puzzle of long standing duration is why with the establishment of agricultural experiment stations in the late 1880's did it take over 40 years for productivity growth to show up? One possible explanation for this "long dry spell" is that agricultural research simply did not turn out anything of significance during its early years. But this is too easy an explanation. The organization of the agricultural research establishment and the quality of its personnel does not appear to have changed abruptly shortly before agricultural productivity growth started to occur. If research wasn't productive in 1900 why should it suddenly become productive in 1930?

Maintenance Research

Some light might be shed on this puzzle by considering the nature and absolute amount of research that was being done during the early part of the 1900's. As observed in a previous section, a major share of the time of experiment station personnel appears to have been devoted to solving immediate and pressing problems faced by farmers. If crop or livestock production was declining or threatened by a disease or problem, it was the job of the researcher to come up with a solution to the problem so that agricultural productivity at least would not decline. In other words, the research effort during the early years of the experiment station system appears to have been devoted largely to maintaining agricultural productivity in the face of a constant surfacing of new problems. Without this research, it is not unreasonable to suppose that agricultural productivity would have declined between 1900 and 1935 instead of remaining fairly constant.

Although there can be little doubt that a certain amount of research is required just to maintain productivity in agriculture, two unanswered questions remain: How much research was required for maintenance purposes in the early 1900's and how much is required today?

As technology has improved over the years, has the amount of research necessary to maintain productivity increased, remained about the same, or declined? One might argue that as varieties of crops and breeds of livestock are bred up to produce greater yields they lose some of their inherent resistance to disease and pests and thus require an increasing amount of maintenance research. On the other hand, it is probably true that because of the increase in the stock of knowledge and the creation of new chemical inputs many diseases and pests which represented major problems for farmers 50 years ago now are nonexistent or routinely controlled. This would imply a decrease in the research required to maintain productivity. At any rate, there doesn't appear to be strong argument either for a greater or a smaller amount of maintenance research necessary to maintain productivity now than was needed in the early 1900's.

The annual expenditures on total agricultural research have, of course, increased greatly over the years. Unless the required maintenance research has increased proportionately with the total, which does not appear likely, the absolute amount of research devoted to technology producing activities, as opposed to maintenance work, also has increased substantially.

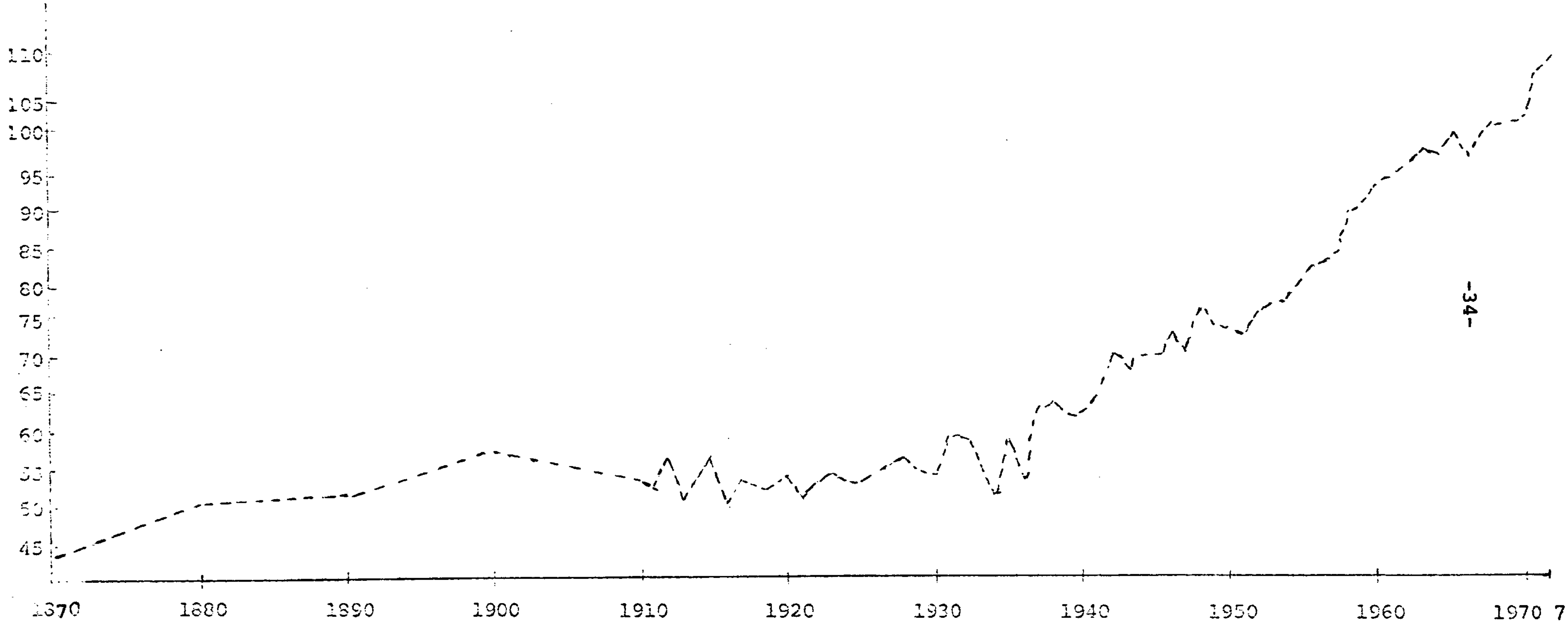
Research Deflaters

In order to accurately gauge the growth in real research inputs over time it is of course necessary to deflate the expenditure figures because of the increase in the general price level. However the use of a common price deflator such as the Consumer's Price Index to deflate

Figure 7

INDEX OF OUTPUT PER UNIT OF INPUT
U.S. AGRICULTURE
1870-1972

1967 = 100



Source: <u>Agricultural Statistics</u>, 1962, p. 54, and 1972, p. 31.
Decennial observations, 1870 to 1910.

research is likely to result in a gross underestimate of past research compared to current figures because professional salaries weigh heavily in total research costs and these salaries have risen faster than the general price level over the past 50 to 60 years.

In order to better approximate the increase in research costs a price index reflecting the average salaries of associate professors in public universities was constructed (see appendix table 4). As shown in table 1, these salaries increased about 8 times between 1915 and 1972 whereas the general price level has increased about 4 times.

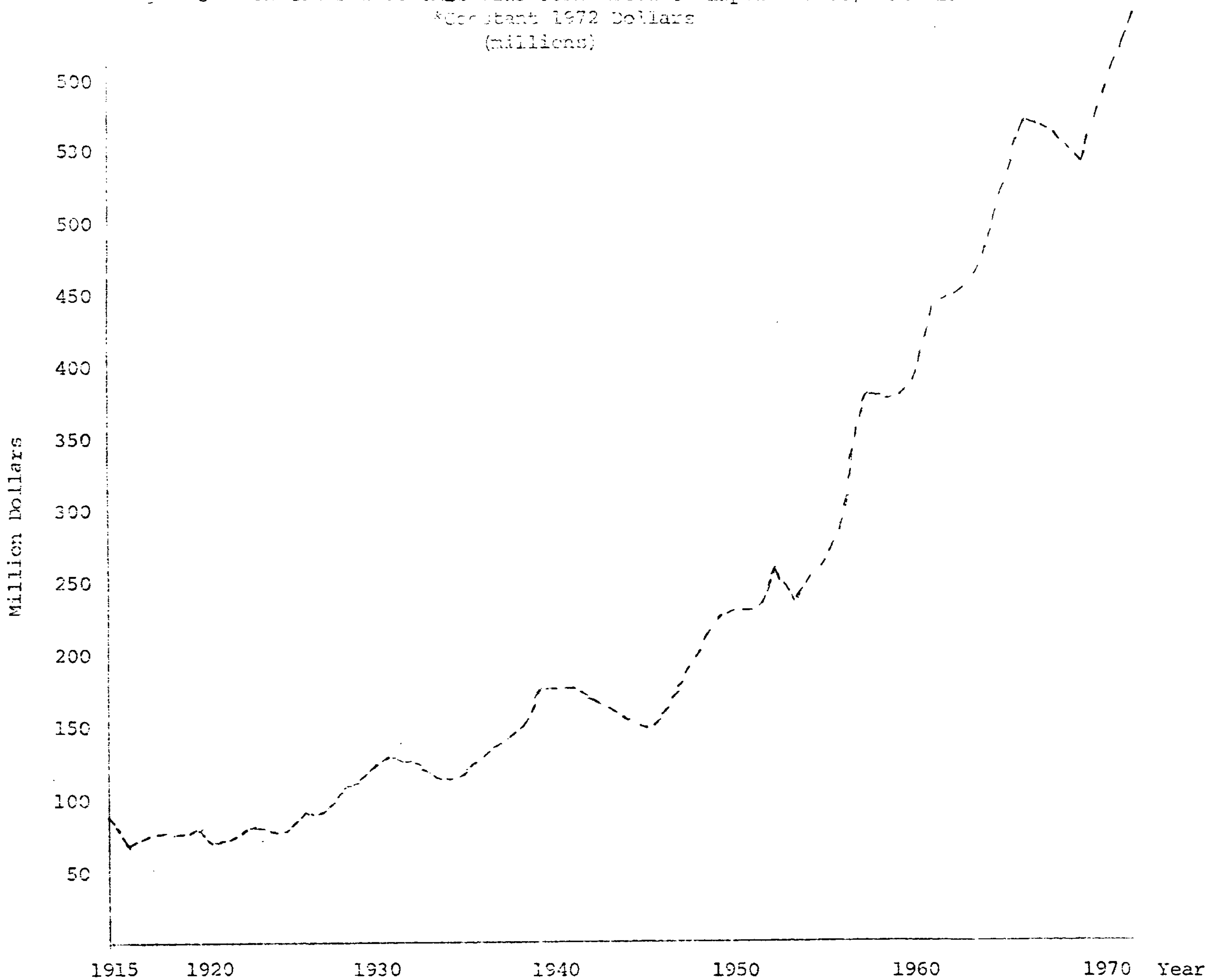
Even when we adjust past research expenditures for the change in research costs using the index of associate professor salaries the average annual research input (state experiment stations plus USDA) during the 1915-1925 period only comes to about 8 percent of the total public research in 1970. As shown in Figure 8, annual real research expenditures begin to climb sharply after 1925, increasing by 57 percent between 1925 and 1930. It does not seem unreasonable to believe that

Table 1. Alternative Research Deflators

Year	Consumer's Price Index	a/ Index of Associate Professor Salaries
1915	24	12
1920	48	16
1930	40	23
1940	34	22
1950	58	40
1960	71	57
1972	100	100

a/ Source: Appendix table 4. Missing years estimated by interpolation.

Figure 8 United States SAES Plus USDA Research Expenditures, 1915-1972
*Constant 1972 Dollars
(millions)



*Source: Appendix Table 5. Deflated by Index of Associate Professor Salaries, 1972 = 100 at least 5 to 10 percent of total current research is required for maintenance purposes. Unless the amount of research required for maintaining productivity has increased greatly since 1930, (in real terms) it seems fairly safe to say that the bulk of the research input before 1925 was required for just maintaining productivity. If so we should not expect productivity to show an increase until after 1930 when research inputs began to surpass the maintenance level by a noticeable margin.

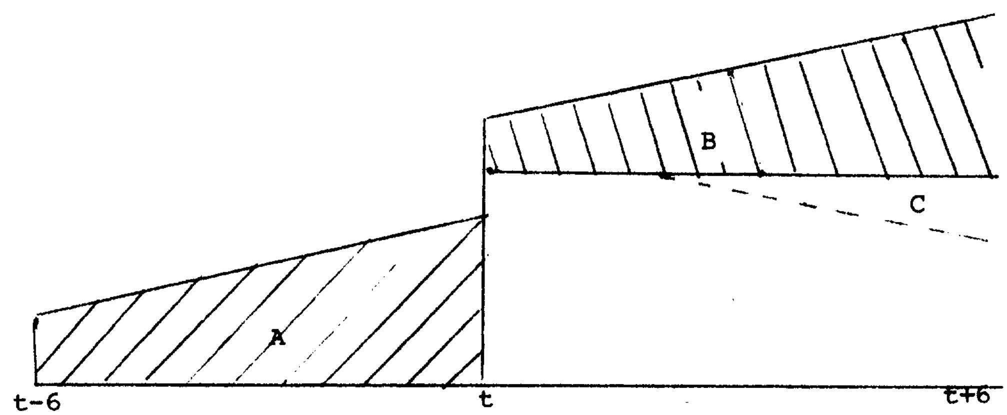
B. MARGINAL RATES OF RETURN TO RESEARCH AND EXTENSION

Methodology

Although it is not our intention to review the methodology which has been used to measure the rate of return to investment in agricultural research, we might say that two general approaches have been utilized. The first which might be called the index number approach uses productivity gains to measure value of inputs saved or consumer surplus stemming from research. (See Schultz 1953, Griliches 1958, Peterson 1967) The second technique which might be called the production function approach involves the use of research as a separate variable in a production function in order to measure its marginal product and marginal rate of return. (See Griliches 1964, Peterson 1967, Evenson, 1968)

Our approach will be to use the index number technique in an attempt to measure the value of inputs saved stemming from the increase in agricultural productivity. In order to obtain a rough, first approximation of the marginal rate of return (as opposed to an overall average) we measure value of additional inputs saved over specified periods stemming from the growth in productivity and value of output. We will assume that the growth in productivity (output per unit of input) during a given 6-year period is the result of research conducted over the preceding 6-year period. This implies a 6 year lag between research and its output. The approach is illustrated by Figure 9. The research costs are represented by area A and the returns (inputs saved) stemming from this research are illustrated by area B.

Figure 9



Estimates By Decades

Because U.S. agricultural productivity began its recent long term growth in 1937, we take 1937-42 as the first of four 6-year periods. The average annual value of additional inputs saved during each of these periods along with the corresponding research and extension inputs are presented in Table 2. For the purpose of computing rates of return both research and inputs saved are deflated by the Consumer's Price Index, 1972 = 100. The fact that research was relatively cheap (compared to inputs saved) in the early years should be reflected in its rate of return. Also in order to take account of private research and extension, public R & E figures are multiplied by two. This implies that private R & E were equal to public expenditures over the period. We shall argue in the following section that this procedure probably biases the estimate of the true rate of return downward.

Table 2 Average Annual Values of Public Research and Extension and Additional Inputs Saved.
(1972 dollars, millions)

	a/ Public R & E		b/ Additional Inputs Saved
1931-36:	$148	1937-42:	$5868
1941-46:	192	1947-52:	6587
1951-56:	322	1957-62:	11,747
1961-66:	671	1967-72:	10,010

a/ Source: Appendix Table 5.
b/ Total inputs saved in year t are obtained by multiplying value of farm marketings plus home consumption by the proportionate change in total factor productivity, 1910-36 = 100. Marginal inputs saved in year t are obtained by subtracting average annual total inputs saved during the preceding 6-year period from total inputs saved in year t.

Matching the research and extension expenditures with the corresponding additional inputs saved, we compute marginal internal rates of return for each of the four 6-year periods. The internal rate of return is that rate of interest which makes the accumulated R & E expenditures at the end of the investment period just equal to the discounted present value of the additional inputs saved at the beginning of the pay-off period, i.e. that rate of interest which makes area A equal to area B in Figure 9. In calculating the internal rate of return, we assume that the average value of marginal inputs saved over the 6-year period will continue into perpetuity. However, because of the high discount rate, these future returns have a small influence on the computed rate of return. The results are presented in Table 3.

Table 3 Marginal Internal Rates of Return to Agricultural Research and Extension by Decades

1937-42:	50%
1947-52:	51%
1957-62:	49%
1967-72:	34%

Biases

Although the computed rates of return to agricultural research and extension in the United States turn out to be very attractive, we have reason to believe that these estimates of the true rate of return are biased downward for a number of reasons. First, no return is credited to maintenance research. In order to capture a return to this activity we would have to know what productivity would have been in the absence of research. Because this information does not exist we do the next best thing by measuring the gain in productivity from a base period. If productivity declines in the absense of maintenance research, we understate the true productivity gains attributable to research. If the information were available to compute the decline in productivity in the absence of any research, we should include area C in Figure 9 as part of the returns. Our procedure implies a zero return to 1921-26 research, when in fact it is hard to believe it was any less productive than 1931-36 expenditures.

The practice of doubling public research and extension in order to include an estimate of private expenditure also should bias the rate of return downward. We can expect that imput prices already include a return to private research and extension. This in turn should increase the input measure and therefore not result in as much productivity gain as would occur if all research and extension were public expenditures.

A third source of downward bias occurs because not all research and extension is aimed at increasing productivity. For example, most of the extension work in home economics is concerned with improving the quality of life not only in rural America but also in towns and cities.

On the other side of the coin, one might argue that the rate of return is biased upward because no charge has been made for the increased education of farm people. However, most of the evidence thus far suggests that the primary role of education in agriculture is to speed up the adoption of new inputs to more quickly move towards an optimum allocation of resources as opposed to a pure "worker effect" (see Welch 1969, Kislev and Shchori - Bachrack 1973, and Huffman 1974). In fact the same argument applies to extension which also yields a return by speeding up the adjustment to new inputs or information.

C. FUTURE RETURNS

Although the marginal internal rates of return to agricultural research and extension appear to have been relatively high, the results presented in Table 3 suggest that this return is beginning to decline. Of course, if research and extension are subject to the law of diminishing returns, it is reasonable to expect a decline in the rate of return to this investment in the absense of additional complementary inputs. Moreover, researchers' and extension agents' salaries probably have increased more rapidly than their marginal productivities in recent years which would also decrease the rate of return to investment in these activities. We might ask, therefore, is there a danger that the marginal rate of return to agricultural research and extension will fall below a minimum acceptable level, say 15 percent, in the foreseeable future?

Over the past two decades (1952 to 1972) public agricultural research and extension expenditures (deflated by the CPI) have nearly doubled each decade for a compound real rate of growth of almost 7.5 percent annually. In 1952 these expenditures totalled $305 million, rising to $509 million by 1962 and $997 million in 1972. If the past 20 year growth rate continues over the next decade, which probably is not out of the realm of possibility in view of the increased concern over world food supplies, public R & E expenditures would reach $1336 million in 1976 and $2000 million in 1982 (1972 dollars).

Predicting future productivity growth is subject to even more uncertainty. If the 1967-72 growth rate continues, the U.S. total factor productivity index would increase from 109 in 1972 to 124 in 1982 (1967=100).

Such an increase does not appear unrealistic particularly if R & E expenditures continue to grow as much as we have assumed. If we further assume a value of agricultural output of $60 billion per year over the next decade, (it was $61 billion in 1972) we can make a rough guess at the expected marginal internal rate of return to 1971-76 R & E expenditures as they are reflected in 1977-82 productivity growth and resources saved. Utilizing the same procedure by which we computed the rates of return presented in Table 3 (doubling public R & E, etc.) we obtain an expected marginal internal rate of return of about 29 percent for 1971-76 R & E expenditures. Hence there does not appear to be any immediate danger of driving the marginal rate of return to investment in agricultural R & E in the United States below an acceptable level, at least over the next several years. In fact the rate of return could increase if productivity growth continues at about the same pace and value of agricultural output increases because of increased exports and higher farm prices.

D. RESEARCH ALLOCATION

The overall rate of return to all research and extension is a composite of the rates of return to investment in thousands of projects and activities. We know that the overall return will be maximized, for a given expenditure, only if the rate of return on all individual projects are equalized. However the output of research is very stochastic in nature. Thus it probably is not very fruitful to try to predict expected rates of return on individual projects. At this level, the return is largely determined by the skill (and luck) of the researcher.

On the other hand, as we look at more aggregative groupings of the total research effort, it would seem to be possible to measure ex post marginal rates of return in order to make predictions about the short run future. Viewing research as a separate variable in a Cobb-Douglas type production function, its marginal product is equal to e(O/R) where e is the production elasticity of research and O/R is dollars of related output per dollar of research (average product). We know there is a large variation between commodities and between states in the average product of research. For example, the average product of corn research is over four times that of cotton research (Table 4). Of course, differences in production elasticities of research between corn and cotton may to a certain extent offset differences in average products, although it is not likely that the ratio of the research elasticities would reach the magnitude of four. Similarly, there is a rather wide divergence between the average products of research in the largest and smallest agricultural states.

Table 4. Average Products of Research
United States, 1969.

Item	Output per Dollar of Research
Corn	$712
Soybeans	672
Wheat	430
Cotton	173
Swine	$485
Beef	442
Dairy	323
Poultry	262
Sheep and Wool	76
Ten largest agricultural states	$351
Ten smallest agricultural states	97

Source: Howard Engstrom,"Productivity Differences in Agricultural Research Between States" Unpublished manuscript, Dept. pf Agr. and Applied Economics, University of Minnesota, May 1972, pp. 6 and 12.

Whether marginal products of research exhibit the same variation or the average products is an open question. Preliminary evidence reported by Maury Bredahl in a Ph. D. dissertation now underway (Agr. and Applied Economics, University of Minn.) suggests that for the most part production elasticities of research are not significantly different between commodities or between large and small states. Therefore it appears fairly certain that the marginal products, hence marginal rates of return to research are higher, the larger are the average products of research. This in turn suggests that if the objective is to maximize output, growth in agricultural research budgets should take place where dollars of related output per dollar of research is the greatest.

This is not to say that marginal rates of return will be equalized if average products or even marginal products are equalized. For one thing, differences in the research lags associated with different commodities will be reflected in different rates of return for the same marginal products. For example, we might expect the lag between research and its output to be longer for livestock than for crops and poultry. If so an optimum allocation of research would be characterized by higher marginal products for livestock than for crops and poultry.

Differences in lags may also be important between experiment stations. If the large stations engage in relatively more basic research than the small stations, where research may be largely adaptive in nature, we may expect the lag to be longer in the large stations. If so the large stations would have to exhibit higher marginal products than the small stations in order to have the same marginal rate of return. On the other hand, it is questionable whether differences in lags could justify differences in marginal products or even average products of the order of magnitude of 4 to 5 times. Needless to say we need more information on differences in marginal products and lags of research between commodities and between experiment stations.

Summary (Part II)

It is helpful to view research as an activity which creates new or improved inputs. Unless our measure of inputs reflects these quality improvements we can expect to observe an increase in output per unit of input. However agricultural productivity in the United States did not begin its sustained long run growth until the early to mid 1930's in spite of the establishment of the federal-state agricultural research system 40 to 50 years hence. One possible explanation for the "long dry spell" is the apparent predominance of maintenance type research during the early years of the research system. Without this research the emergence of new diseases, pests, and problems probably would have resulted in a reduction in agricultural productivity.

Rough estimates of the marginal internal rate of return to agricultural research in the United States yield figures of around 50 percent up until the early 1960's. The estimate for the late 1960's and early 1970's reveals a decline in the rate of return down to about 34 percent. Although the marginal rate of return to agricultural research in the United States appears to be declining, there does not appear to be much danger that it will fall below a minimum acceptable level such as 15 percent at least during the next 5 to 10 years.

Substantial differences in average products of research between commodities and between states, suggests possible differences in the marginal rates of return between various kinds of research and between experiment stations. Differences in the lags of research between commodities and between experiment stations could justify some differences in marginal products, although it is questionable whether marginal product differences of the order of magnitude of 4 to 5 times are justified at least from an economic standpoint.

Appendix Table 1

Indices of Farm Output and Land in Farms, 1870-1969

Year	Index of Farm Output (1947-49=100	Land in Farms (1950=100)	Land Harvested in Preceding Year (1950=100)
1870	23	49.4	nr
1880	37	74.5	48.3
1890	43	84.8	63.8
1900	56	106.6	82.2
1910	61	118.2	90.4
1915	68	-	-
1920	70	119.8	101.2
1925	70	118.4	100.0
1930	72	116.8	104.3
1935	72	126.6	85.8
1940	83	113.3	93.3
1945	96	108.9	102.5
1950	100	100.0	100.0
1954	112	88.9	96.8
1959	123	68.8	96.7
1964	133	58.6	90.4
1969	140	48.0	nr

Source: Col. 1: Historical Statistics, Series K-190, p.288; Agricultural Statistics, 1972, p.537.
Col. 2&3: Agricultural Statistics, 1962, p.512; 1972, p.504.

Appendix Table 2

Farm Labor Employed, and Workers Claiming Farm Employment, 1870-1969 (1947-1949 = 100)

Year	Farm Labor Employed 1/	Workers Claiming Farm Employment 2/
1870	--	66.9
1880	--	83.9
1890	--	97.1
1900	--	106.6
1910	132.4	113.2
1915	132.8	--
1920	132.1	111.8
1925	127.4	--
1930	122.1	102.3
1935	124.4	
1940	107.3	
1945	97.7	
1950	97.0	
1954	84.5	
1959	71.7	
1964	59.7	
1969	44.9	

1/ Farm Labor Employed are those people actually employed in farming in the week preceding the taking of the census, and includes farm operators working one hour or more per week, family workers working fifteen or more hours per week, not for cash payment, and hired labor.

2/ Workers Claiming Farm Employment are those people who claimed farm employment as their occupation. The census did not attempt to determine whether or not they were actually employed at the time, or if they were unemployed, casual (*e.g.* student) workers, or retired workers.

Source: Farm Labor Employed: 1910-1954, *Historical Statistics*, series D-73, D-74, D-75, p. 280; 1930-1969, *Agricultural Statistics*, 1972, p. 523. Workers Claiming Farm Employment: 1870-1930, *Historical Statistics*, series D-37, p.72.

Appendix Table 3

Capital Invested in Farm Lands and Buildings, Not Including Farm Machinery
(1947-1949 = 100)

Year	Capital Invested $ Millions	Index of Capital Invested
1870	7444	18.7
1880	10197	33.0
1890	13279	47.1
1900	16615	63.6
1910	34801	119.1
1920	66316	105.4
1925	49468	90.2
1930	47880	91.7
1935	32859	76.6
1940	33642	76.7
1945	53889	95.7
1950	75261	100.0
1954	97583	116.1
1959	128988	141.5
1964	159432	164.4
1969	201485	175.7

Source: U.S.D.A., Agricultural Statistics, 1972, p. 504; Consumer Price Index for 1947-1949 base used to adjust column 1 before the index was constructed.

Appendix Table 4

Salaries of Associate Professors
in Public Universities
9-month basis
(current dollars)

1915	—	1934	—	1953	$6635
1916	$1871	1935	$2903	1954	—
1917	1944	1936	2973	1955	6940
1918	2012	1937	3144	1956	—
1919	2183	1938	3189	1957	6980
1920	2447	1939	—	1958	7442
1921	2744	1940	3272	1959	8124
1922	3007	1941	—	1960	8545
1923	3049	1942	3324	1961	8546
1924	3084	1943	—	1962	8961
1925	—	1944	—	1963	9414
1926	3160	1945	—	1964	9991
1927	3197	1946	—	1965	10,517
1928	3298	1947	—	1966	11,243
1929	3359	1948	5346	1967	12,022
1930	3345	1949	5612	1968	12,864
1931	3418	1950	—	1969	13,577
1932	3379	1951	6145	1970	13,792
1933	3100	1952	—	1971	14,887
				1972	14,887

Sources: 1904-42: George Stigler, "Employment and Compensation in Education" NBER Occasional paper No. 33, 1950
1948-72: American Association of University Professors Bulletin, respective years.

Appendix Table 5

Public Research and Extension
(current dollars, millions)

	*SAES	USDA	Extension
1915	4.6	6.0	3.5
1916	3.8	5.2	4.9
1917	3.8	5.8	6.2
1918	4.2	6.3	11.3
1919	4.2	6.9	14.7
1920	5.0	7.7	14.7
1921	5.2	7.8	16.8
1922	6.3	8.2	17.2
1923	7.0	8.5	18.5
1924	7.6	8.4	19.1
1925	7.3	9.3	19.3
1926	8.9	10.2	19.5
1927	9.3	10.5	20.1
1928	11.4	11.7	20.7
1929	12.0	13.8	22.9
1930	13.1	15.5	24.3
1931	12.5	16.7	25.4
1932	12.1	16.1	24.3
1933	11.4	13.1	22.0
1934	11.1	11.1	19.8
1935	11.1	11.4	20.4
1936	12.1	14.4	28.3
1937	12.9	16.4	30.0
1938	14.8	18.0	31.6
1939	15.6	23.3	32.4
1940	16.8	22.1	33.1
1941	16.7	21.4	33.5
1942	17.7	22.0	34.5
1943	17.5	21.8	35.0
1944	18.8	22.0	36.3
1945	19.8	22.9	38.2
1946	23.6	27.6	44.6
1947	28.1	33.2	53.7
1948	35.3	38.2	60.2
1949	39.9	46.0	67.2
1950	48.2	46.8	74.6
1951	50.5	45.1	77.6
1952	56.4	45.0	81.8
1953	60.0	45.3	86.8
1954	68.0	46.0	91.6

Appendix Table 5 (continued)

	*SAES	USDA	Extension
1955	73.8	53.4	100.7
1956	85.4	59.6	110.1
1957	92.2	86.6	118.2
1958	105.9	83.7	128.7
1959	110.3	99.0	136.0
1960	120.3	105.2	141.7
1961	127.3	128.9	149.4
1962	142.1	126.4	159.2
1963	151.3	136.1	168.6
1964	169.3	149.8	177.9
1965	181.8	192.5	188.9
1966	223.4	212.7	201.2
1967	239.7	218.5	213.7
1968	261.5	219.5	225.5
1969	274.0	213.2	242.0
1970	296.1	238.7	290.7
1971	319.3	263.1	331.9
1972	348.8	294.0	354.4
1973	382.9	303.9	385.1

*Federal plus nonfederal funds available. Excludes fees and sales.

Sources: SAES: 1915-60, "Report on the Agricultural Experiment Stations", published by Office of Experiment Stations through 1953, and Agricultural Research Service from 1954 through 1960. 1961-73, "Funds for Research at State Agricultural Experiment Stations", Cooperative State Experiment Station Service, U.S. Department of Agriculture.

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