Agricultural Postharvest Technology and Marketing Economics Research

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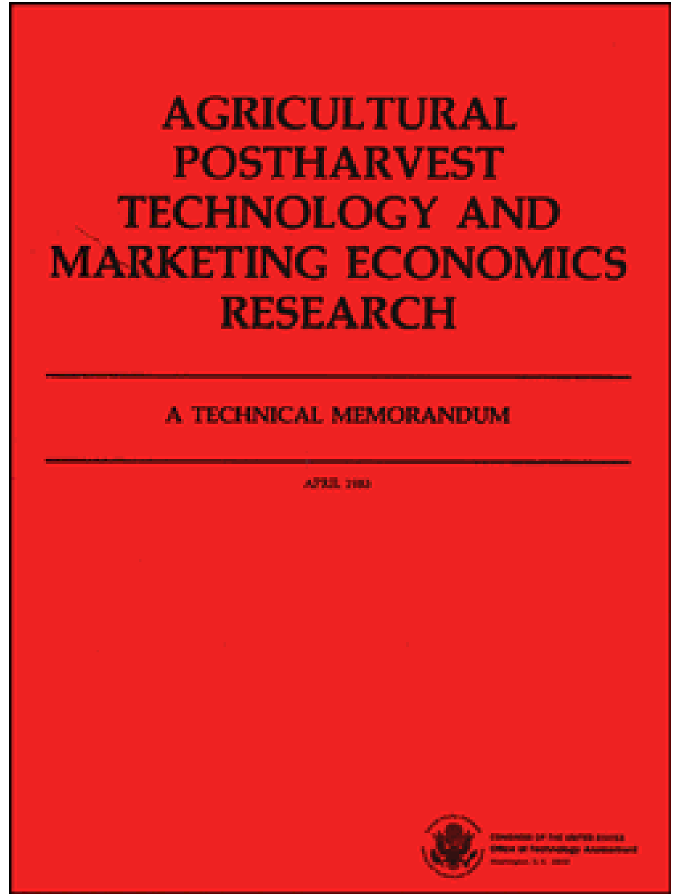

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Foreword

The food and agricultural research establishment today is facing new problems that place severe strains on the research system. A previous OTA report, An *Assessment of the United States Food and Agricultural Research System,* documented these concerns and provided policy options to Congress.

Postharvest technology and marketing economics (PHTME) research is one area of agricultural research in which these problems and concerns are acute. The U.S. Government funds PHTME research, but public support of PHTME research is being questioned.

The Office of Management and Budget and the U.S. Department of Agriculture have argued that it is no longer necessary to increase investment in PHTME research, implying that private firms have sufficient resources to conduct their own research. The executive branch has made numerous attempts to decrease public support of PHTME research.

At the request of the House Agriculture Committee, OTA conducted an analysis of PHTME research as a follow-up to the OTA study on food and agricultural research. This memorandum presents OTA's findings and conclusions regarding the role of the public and private research participants in PHTME research, the benefits and burdens of PHTME research, trends in PHTME research funding, quality of PHTME research, and management of PHTME research in the public sector,

The author of this memorandum is Michael Phillips. OTA particularly wishes to acknowledge the panel members from the OTA study on food and agricultural research who contributed to this memorandum and the public and private sector PHTME research experts who participated in an OTA workshop and reviewed drafts of the final report.

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Chapter 1

Executive Summary

INTRODUCTION

During 1982, American consumers spent $298 billion for food. Approximately 30 percent of that actually went toward on-farm production costs. The remainder was spent on postharvest activities and marketing.

The phrase agricultural postharvest technology and marketing economics (PHTME) includes all technological and economic transformations that occur to agricultural products between harvest and consumption. PHTME encompasses storage, assembly, processing, packaging, warehousing, transportation, and distribution of agricultural products through the institutional food trade and wholesale and retail outlets.

The U.S. Government today funds research on these subjects, but the question is whether or not it should continue to do so. Accordingly, the House Agriculture Committee requested that OTA examine the role of the public sector in PHTME research. This memorandum presents the results of that examination, focusing on:

1. the development of public sector research;
2. identifying and, where possible, measuring the costs, benefits, burdens, and quality of the research;
3. examining the role of public and private research participants;
4. evaluating public sector research programs; and
5. findings and conclusions for Congress.

The OTA analysis finds that U.S. labor and capital productivity of postharvest technology and marketing sectors is poor relative to on-farm productivity and that increases in postharvest technology and marketing costs have contributed significantly to the U.S. inflationary spiral since 1972. Concurrently, there have been significant declines in research on postharvest technology and marketing.

The United States relies on Federal agencies, State agricultural experiment stations (SAES), universities, and private industry to carry out PHTME research. Historically, the rationale for public sector agricultural research has been that farmers and other businesses have neither sufficient economic incentive nor scale of operation to conduct their own research. In addition, many experts believe that a competitive agricultural structure fosters more rapid adoption of new technology; free information, as supplied by public research institutions, is one technique used to promote such a structure.

The food and agricultural research establishment today is facing new problems that place severe strains on the research system. * In response, there is an ongoing search for ways to improve the effectiveness of the research system while reducing costs. Because of this, some of the past arguments in favor of publicly supported PHTME research are being questioned.

Some executive branch members, including the U.S. Department of Agriculture (USDA) and the Office of Management and Budget, have argued that it is no longer necessary to increase investment in certain forms of research—including PHTME research—implying that private firms have sufficient resources to conduct their own research, and that information ultimately will become available to smaller firms. Thus, the executive branch has made a number of attempts to decrease public support for PHTME research over the last 10 years,

* These problems are discussed and analyzed in detail in the 1981 OTA report An *Assessment of the United States Food and Agricultural Research System.*

FINDINGS AND CONCLUSIONS

An earlier OTA study, An *Assessment of the U.S. Foodand Agricultural Research System,* determined that the United States does not have well-articulated and clearly achievable national food and agricultural goals. This is a major deterrent to directing PHTME *or* other research efforts. Vague or implicit goals provide little help in formulating policies or giving the research community direction. For example, such stated goals as "making two blades grow where one grew before, " or "provide an ample supply of food," or "provide food at a reasonable price to consumers" are open-ended, unmeasurable, and do not provide any specific guidance to the research community. What is an "ample supply" or a "reasonable price" for food? Have we already achieved this goal or is it a long way off? How do we know? Such questions must be answered for a goal to be useful in policy formulation and in planning a research agenda.

Examples of what more explicit goals *might* be for the PHTME sector are:

1. Discounting inflation, real retail prices of agricultural products should be held to less than an X percent increase within the next decade.
2. The total volume of nonrenewable energy consumed in the PHTME sector should be held constant during the next 5 years, and should decline by X percent within 10 years.

By specifying explicit national goals, society, through its elected representatives, notifies the research community of societal wishes. Research then can be directed toward attaining these goals.

Research Benefits and Beneficiaries

PHTME research provides a *range of benefits,* including:

- *Increased Productivity and Reduced Real Cost of Food.* –Productivity in the PHTME sector is lagging relative to on-farm productivity. Seventy percent of consumers' food cost is attributable to food assembly, processing, transporting, and distribution. Opportunities exist to increase postharvest productivity by developing new or improved technologies that will reduce the cost of those operations that add to the cost of food once it leaves the farm. Such technologies should: 1) increase labor productivity, 2) improve processing and preservation, and 3) increase marketing and distribution efficiency.
- *Ehhanced Food Quality, Safety, and Nutrient Content.* —PHTME research could improve operations such as food storage, handling, shipping, intermediate processing, packaging, delivery to merchants, and shelf life, and thus influence nutritional value and product quality. For instance, some nutrients, notably vitamins and fats, are sensitive to changes in pH, oxygen, heat, light, and can be depleted during transport, storage, or processing, Technologies could be developed to inhibit mycotoxins and infestation by insects and rodents. PHTME technologies also have helped improve diets through food enrichment—e.g., addition of vitamins B_1, B_2, and niacin to cereal products, vitamin D to milk, and iodine to salt.
- New *or Improved Food Products.* —Research can help develop nontraditional food sources as alternatives to today's highly capital- and energy-intensive food production and processing. Substitute foods and ingredients already have been developed by using diverse raw materials. For example, raw soybeans are now used to produce soy flour, protein concentrate, soybean isolates, or textured products. Because the importance of plant protein in diets is expected to increase relative to meat, fish, and egg protein, research in this area may have great potential for providing food to the world population at reduced costs.
- *Information for Decsionmaking.* –The ME of PHTME is marketing economics research. Work in this area helps provide information to farmers, processors, distributors, consumers, and policymakers, which improves the effectiveness of their decisionmaking. Information can range from economic forecasts on grain crops to cost-benefit analysis of food

regulations—e.g., food labeling, marketing orders, and food safety.

- *Industry Competitiveness.* —Some PHTME research measures the competitive relationships among firms providing a similar set of products or services. This research can examine factors such as the degree of market concentration, barriers to entry, types of competing organizations, and regulations that affect competitive behavior. The information provided is useful for: 1) affected businesses and the public to help understand the forces shaping the industry, 2) business groups developing long-range plans, and 3) policymakers designing alternative legislative proposals or regulations to ameliorate, maintain, or enhance competitive relationships.

PHTME research benefits can accrue to a number of *beneficiaries,* including:

- *Farm Producers.* —By improving storage, processing, retailing, and transportation systems, postharvest technologies enhance the value of farm commodities by letting producers distribute the sale of products over time. Thus, farmers can obtain increased income by selling products off-season or in nonproducing areas. In addition, marketing services increase information available to producers, increasing their chances to sell at more favorable market prices.
- *Consumers and General Economy.—Tech*nological changes in the postharvest or marketing sectors that reduce the costs of product transformation or marketing services can reduce retail prices for consumers. Similarly, consumers also can benefit from improved market or price information which leads to more informed decisionmaking. In addition, consumers benefit if food quality, nutrition, safety, and convenience are improved.

  The distribution of PHTME benefits varies with income. OTA found that the ratio of consumer benefits to family income was almost four times higher for the lowest income class than for the highest. Thus, PHTME technologies have a greater beneficial impact on low-income families than on high-income families.
- *Marketing Firms.* —Marketing firms also can benefit from PHTME research, depending on the competitive structure of the industry. In a competitive economic environment, firms that adopt more efficient and productive technologies might pass the savings on to consumers. This could provide a higher price for farm producers and lower retail costs for consumers. Some firms may retain some of the cost savings in the form of increased profits. The PHTME sector has elements of both economic environments depending on the commodity or food product.
- *Labor and Other Input Suppliers. —New* technologies can foster increased labor productivity, allowing for increased wages and salaries without necessarily increasing retail prices. The result can be a wider variety and more abundant supply of goods and services. However, when more productive postharvest technologies are adopted, the displaced labor force must find other employment.

Trends in Research Funding and Relationship to Research Beneficiaries

In comparison to production research, PHTME research has not been a major public sector priority. Combined USDA and SAES expenditures for PHTME research equaled $260 million in 1981 and accounted for 18 percent of total USDA and SAES agricultural research expenditures, while production research accounted for 69 percent. Further, public expenditures for PHTME research in constant dollars have *increased only 1.6* percent between 1966 and 1981. Since 1978, constant dollar expenditures for PHTME research have *declined* 8 percent.

USDA and SAES individual expenditures, however, show two different and distinct patterns. USDA expenditures for PHTME research (including funds transmitted to SAES and other agencies) *decreased 17* percent in constant dollars between 1966 and 1981. In contrast, SAES expenditures for PHTME research *increased 32* percent in the same period. By 1980, SAES had increased its share of the total public expenditures for PHTME research from 38 to 51 percent.

The majority of SAES funds for PHTME research come from State appropriations. These appropriations increased from 43 to 56 percent of SAES funds for PHTME research between 1966 and 1981. Federal funding of SAES postharvest research from 1966 to 1981 declined from 53 to 38 percent. Thus, State appropriations now provide over one-half of the expenditures for PHTME research in the SAES. This is important when considering the relationship between research beneficiaries and source of funding.

OTA found that the majority of the benefits from PHTME research flow to those regions and States with high concentrations of population. In all geographic regions except the Northeast, the total benefits accruing to residents outside the region where the research is conducted are at least four times greater than the benefits accruing to the residents in the region.

The bulk of PHTME research at present is conducted in the major farm-producing States and is mainly supported by State appropriations. Thus, taxpayers in the major agricultural States, such as the Midwest States, are subsidizing PHTME research for consumers in the less intensive agricultural States, such as in the Northeast. When research benefits the wider public, funding can be more equitably provided by the Federal Government. The inequitable distribution of costs and benefits of PHTME research argues for increased Federal Government support.

Quality of Research

In the debate between the executive branch and Congress on funding PHTME research, critics frequently point to declining quality of the research, faculty, and graduate students as reason for not supporting public PHTME research. Such assertions are subject to question. A review of relevant literature failed to find any formal methods for evaluating the quality of research. Thus, the perception that the quality of agricultural research is declining is based solely on informal judgments.

This study attempted to find credible ways of measuring the quality of PHTME research. One measure examined was the number of citations of: 1) PHTME publications in peer-reviewed journals, and 2) PHTME patents. Using these approaches, OTA found that PHTME is providing a body of scientific literature that is roughly comparable to that produced in other applied sciences. Further, PHTME research is providing patents that are subsequently cited by the private sector. On the other hand, the OTA review was consistent with the view that PHTME researchers may not be aware of relevant research in closely related scientific disciplines and that some research programs could be better organized.

Public and Private Research Sectors

Public and private participants contribute to PHTME research. However, no fixed pattern has developed with respect to kinds of research performed by USDA, SAES, and industry, and no principle has been apparent in determining the role of each. Decisions as to who performs what research in the public sector invariably have been decided ad hoc, and are often arbitrary, expedient, and inconsistent from year to year. These decisions also are easily influenced by immediate pressures rather than being guided by uniform, long-range principles. More clearly defined roles could help each sector contribute more fully in their respective areas.

Role of Private Sector Research

The private sector is motivated by market incentives. If management believes that the private rate of return will be substantial, resources are allocated for research. This memorandum estimates that the social returns from private research are approximately double the private investment returns. Some distinguishing characteristics of private sector PHTME research need to be taken into account when considering its role: 1) most private sector research tends to be focused on short-term applied problems; 2) longer term inquiry into biological, economic, and social system structure and function would not tend to be supported by private sector research; and 3) even though there may be substantial social benefits from private research, private industry generally is not concerned with the net social benefits from its research endeavors and is reluctant to release information that might cause technologies or processes they use to be adopted widely before they benefit from the economic returns that accrue to new, cost-cutting technologies.

Thus, the areas of PHTME research that are *primarily in* the private sector domain include: 1) *patentable processes and* techniques-research that most nearly fits short-term applied problems; 2) *research to meet Federal and State regulations*—research needed for a business to stay in operation while meeting social objectives; and 3) *research to maintain or gain new clientele.*

Role of Public Sector Research

The OTA study shows public sector research to be justifiable for at least three reasons: 1) because benefits are distributed beyond those who bear the costs, and substantial social advantages are derived from both public and private research; 2) in the absence of public sector support and guidance, PHTME research might be biased strongly toward mechanical and chemical technologies, since economic returns can be extracted in the short run; and 3) for those situations where private research might be detrimental to industry competitiveness, a mix of public and private research may best preserve competition or reduce market power.

Thus, the areas of PHTME research that *are primarily* in the public sector domain include: 1) *basic knowledge, 2) information to support policymakers and government action and regulatory agencies so* that informed decisions can be made, and 3) *research to enhance competition,* through development of technologies and information that is disseminated to the public.

Joint Public and Private Sector Research

Some areas of PHTME research merit both public and private sector research. This is the case when social returns exceed private profit because a large share of the gains from the private research can be captured by other firms and consumers. Thus, research that is best done jointly by the private and public sectors includes: 1) new food sources and their development, 2) naturally occurring food contaminants, and 3) yields in relation to productivity versus nutritional components,

Management of USDA Research

Three research agencies in USDA conduct and fund PHTME research: the Agricultural Research Service (ARS), Economic Research Service (ERS), and Agricultural Marketing Service (AMS). Each agency reports to a different USDA Assistant Secretary, a factor that complicates planning and coordinating PHTME research.

ARS is not organized to manage, conduct, or be responsive to broad regional and national PHTME research needs. When the 1972 reorganization of ARS transferred line responsibility to four regional administrators, the National Program Staff was left without direct responsibility for program development, staff selection, and resource allocation. This reduced the ARS ability to plan, manage, and conduct research on broad problems. This agency thus lost national technical leadership. In addition, PHTME research is identifiable as an individual research entity at the national level, but no such distinction exists at the regional or area level. Not only does this provide opportunities for duplication, but it increases the likelihood that broad regional and national PHTME research will not receive adequate attention and that Federal funds appropriated for these purposes will be used inefficiently.

ERS allocates a large part of its resources to PHTME research; nevertheless, the expenditure is not identified as a separate research activity. PHTME research is fragmented, with an accompanying loss in direct cooperation with ARS laboratories and university departments of agricultural economics.

AMS is an action agency with a small research program that focuses on wholesale market development. AMS distributes market news to the agricultural community, inspects and grades agricultural food products, and conducts other regulatory activities. Few AMS activities are devoted to market development. Its research program suffers both by being isolated from the main PHTME research programs and by being located in an action agency which, given its mission, has a low priority for this research. A research program that supported the major mission of the agency probably would be of more value.

USDA and SAES Roles

The allocation of research responsibilities between USDA and SAES is distributed logically. The Federal Government, either intra- or extramurally, must give highest priority to problems of national significance, and must, as a part of this responsibility, be aware of States and private industry contributions toward national objectives. SAES, insofar as Federal funds are concerned, give highest priority to State and regional concerns. As more is known about the beneficiaries of this research, and in particular the relationship between funding source and beneficiaries, there is increasing evidence to support a major Federal effort in PHTME research because for most technology development, the beneficiary is the U.S. public generally rather than any one State or region. Thus, the Federal role includes: 1) providing leadership in identifying national research priorities and conducting supporting research with a regional or national emphasis; 2) supporting SAES so they conduct research of special concern to a locale, State, or region; 3) assuring development of new, fundamental knowledge by supporting or conducting basic research; and 4) maintaining a research capability for conducting basic and applied research in support of unique Federal missions.

Chapter 2
Introduction

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Chapter 2
Introduction

American consumers spent an estimated $298 billion dollars for food during 1982. Approximately 30 percent of that amount was attributable to on-farm production activities. However, $214.5 billion of the consumer food bill, the remaining 70 percent, was attributable to postharvest activities and marketing.

Before they finally reach consumers, agricultural commodities produced on the farm must be assembled, processed, packaged, warehoused, stored, transported, and distributed through the institutional food trade wholesale and retail outlets. The subject of this memorandum is research pertaining to all the technological and economic transformations that agricultural products undergo after leaving the farm up to the time of their consumption—henceforth referred to as postharvest technology and marketing economics (PHTME) research.

The U.S. Government funds PHTME research, but the question is whether or not it should continue to do so. The food and agricultural research establishment today is facing new problems that place severe strains on the research system. As a result, there is an ongoing search for ways to improve the effectiveness of the research system while reducing costs. Because of this, some of the arguments in favor of publicly supported PHTME research are being questioned.

Some executive branch agencies, including the U.S. Department of Agriculture (USDA) and the Office of Management and Budget, have argued that it is no longer necessary to increase investment in certain types of research, including PHTME research, implying that private firms have sufficient resources to conduct their own research and that the information ultimately will become available to smaller firms. Thus, the executive branch has made numerous attempts to decrease public support for PHTME research over the last 10 years.

This memorandum presents OTA's findings and conclusions regarding the nature of the benefits and burdens of PHTME research, trends in research funding and the distribution of benefits from PHTME research, the quality of PHTME research, the roles of public and private research participants in PHTME research, and the allocation of public research responsibilities between USDA and State agricultural experiment stations (SAES). Public and private sector investment in PHTME research is discussed in chapter 3. The benefits, burdens, and quality of PHTME research are discussed in chapter 4. The roles of public and private research participants are discussed in chapter 5, and the policy and management of USDA research programs are discussed in chapter 6.

As background for the discussion in the chapters that follow, this chapter provides a brief orientation to PHTME research. PHTME research focuses on the economic and technological transformations that agricultural products undergo once they leave the farm, so the chapter also discusses the sector of the economy in which these transformations take place, namely the food marketing sector.

ORIENTATION TO PHTME RESEARCH

PHTME research has two primary components: 1) postharvest technology research, which focuses on the biological, chemical, or mechanical transformations of agricultural products subsequent to harvest; and 2) agricultural marketing economics research, which focuses on the economic aspects of marketing agricultural products.

Postharvest technology research is biologically or physically oriented. Such research thus complements physically oriented production research (e.g., research concerned with the soil, water, and air resources and the production of farm crops). Some postharvest technology research focuses on the biological or chemical properties (e.g., composition, quality, safety, nutritional value) of agricultural products that affect the handling, storage, transportation, preservation, and effective use of such products. Other postharvest technology research focuses on the mechanical technologies used to assemble, process, package, warehouse, store, transport, and distribute agricultural products.

Agricultural marketing economics, like economics generally, is a social rather than a biological or physical science. Marketing economics focuses on the economic aspects of human and organizational behavior. Agricultural marketing economics takes two components of this behavior into account. One is behavior pertaining to demands of consumers for the combination of products and services that make up the national food supply. The second is behavior pertaining to efficiency with respect to the processing and distribution of the national food supply. In order to maximize profits, individual firms seek to minimize the resource requirements and consequently the costs of the marketing functions they perform. Based on the above components, agricultural marketing economics research is concerned with three broad areas: efficiency analysis, price analysis, and policy analysis. Efficiency analysis is concerned with the problems of increasing efficiency in the procurement, processing, and distribution of farm products. Price analysis focuses on problems related to agricultural product and input prices over time. Policy analysis is concerned with the expected or observed effects of alternative policies that influence the marketing of agricultural products (1).

PHTME research is conducted and supported by both the public and private sectors, although the types of PHTME research they conduct reflect the two sectors' differing orientations. The major participants in the public sector are USDA and SAES. Some lesser funds for PHTME research are made available by Federal agencies other than USDA, but those agencies are not considered in this technical memorandum. Also not considered here are certain non-land-grant universities, including those publicly and privately financed, that have research programs supported by public funds.

Research participants in the private sector include foundations, industry, and industry associations. Industry and industry associations' financial investments in PHTME research can be quite large, although the direction of this private research can be quite different from that of public PHTME research.

Private Sector Research

Private sector PHTME research is generally motivated by economic concerns such as profit and growth. If management expects that the rate of return will be substantial, resources are set aside for research.

Because of this profit orientation, PHTME research in private industry primarily takes the form of new product development. This includes product line extensions (e.g., new flavors, colors, package sizes, or other variations introduced to supplement existing products) as well as product improvements (e.g., modifications in the formulation of existing products, or improvements in the technologies used to process existing products). The profit orientation also leads private industry to conduct economics research, for example, in the form of demand and supply forecasts that can be used by an individual firm to make decisions concerning production levels, pricing, or purchasing of inputs.

Some firms conduct PHTME research in order to comply with or mitigate the impacts of government regulations, including those for food safety, food quality, environmental pollution levels, and labeling. This is sometimes referred to as "defensive research. " For example, where a firm is required to sell a safe and wholesome product, it may have to undertake research to establish the parameters for the safe use of its product. If a firm uses nutritional labeling or makes a nutritional claim about the product in its advertising, it must have conducted the necessary research to support the nutritional label or advertising claim.

Public Sector Research

PHTME research conducted in the public sector is focused on the concerns of society as a whole—maintaining costs of food at a reasonable level, enhancing product quality, protecting the environment, efficiently using energy and renewable resources, increasing productivity, ensuring the safety of the food supply, using agricultural products for industrial and fuel purposes, and others.

PHTME research addresses these concerns through effort in the following types of activities:

- development of new and improved technologies and methods for processing and distribution of food products in order to increase efficiencies and improve competition;
- development, improvement, and/or adaptation of technologies for prevention or reduction of product losses caused by microbial contamination, insects, rodents, birds, etc.;
- identification of potential hazards to health and safety resulting from food or work environment and development of methods for elimination or reduction of the degree of hazard;
- development of technology for maintaining optimum quality and acceptability of food products;
- pollution reduction in the water, soil, and atmosphere through new processing technologies, waste management, and use of biodegradable materials;
- development of methods, processes, and techniques for conservation of energy and the use of alternative sources of energy;
- development of methods for enhancing the properties and uses of agricultural products;
- identification and forecasting of demand and supply relationships for agricultural commodities for use in firms as well as public policy decisionmaking; and
- evaluation of the structure and Performance of the food industry to measure the degree of industry competitiveness.

DESCRIPTION OF THE FOOD MARKETING SECTOR

Conceptually, the food marketing sector of the U.S. economy can be thought of as a link between farmers and consumers. This link has three critical dimensions: physical, pecuniary, and communicative. The physical dimension involves the flow of agricultural commodities from the farmer through the assembler, processor, wholesaler, and retailer to the consumer. The pecuniary dimension involves the flow of dollars from consumers of agricultural commodities back to the producers. The communicative dimension involves the flow of information about the nature of the physical and pecuniary flows (e.g., information about supply and demand conditions) to participants in the market system.

More concretely, the food marketing system can be described in terms of the participants in the system. Participants in the marketing system include the multitude of institutions and institutional arrangements that exist to facilitate the flow of information and trading—e.g., commodity exchanges, central markets, auctions, trade organizations, and the news media. Other participants in the system include organizations which render services as part of the system—e.g., financial institutions, processing firms, warehousing companies, retail firms, and transportation firms. The Federal Government is also involved in the system in its capacity as regulator—e.g., of food safety, grades and standards, nutrition, and competition. Inputs into the marketing system include labor, building materials, packaging, and equipment. These inputs become part of the products that are marketed.

The food marketing sector can also be described vis-a-vis the food production sector in terms of its contributions to total consumer food expenditures, its contribution to the output of the food and fiber system, its contribution to employment, and its consumption of energy.

Contribution to Consumer Food Expenditures

Consumer expenditures on U.S. farm-produced food have been consistently increasing on an annual basis since 1971 (see table 1). The trend in both on-farm production costs and marketing

Table 1.—Consumer Expenditures on U.S. Farm-Produced Foods, 1971-82

Year	Consumer expenditures (in billions)	Farm value (in billions)	Marketing bill (in billions)	Marketing bill as a percentage of consumer expenditures
1971	$114.6	$36.1	$ 78.5	68.4%
1972	122.2	39.8	82.4	67.4
1973	138.8	51.7	87.1	62.8
1974	154.6	56.4	98.2	63,5
1975	169.0	55.6	113.4	67.1
1976	183.7	58.3	125.4	68.3
1977	192.3	58.0	134.3	69.8
1978	214.3	69.4	144.9	67.6
1979	241.2	78.4	162.8	67.5
1980	260.8	81.1	179.7	68.9
1981	285.0	82.9	202.1	70.9
1982	298.0	83.5	214.5	71.9

SOURCE: U.S. Department of Agriculture, Economic Research Service, 1982.

costs from 1971 to 1982 generally has been upward. In 1982, total consumer expenditures on food reached a high of $298 billion: while the amount attributable to on-farm production costs was $83.5 billion (28 percent of the total), the amount attributable to marketing costs (i. e., the difference between the farm value or payment to farmers for foodstuffs and consumer expenditures for these foods) was $214.5 billion (71.9 percent of the total). From 1971 to 1982, the percentage of consumer food expenditures attributable to marketing costs ranged from a low of 62.8 percent in 1973 to a high of 71.9 percent in 1982.

Increases in the specific components of the food marketing bill from 1971 to 1982 are shown in table 2. By far the largest component of the bill is labor costs. Since 1971, labor costs have been consistently increasing on an annual basis; in 1982, they accounted for $97.2 billion, or 45 percent of the total $214.5 billion marketing bill, Other components of the marketing bill include packaging, which accounted for 11 percent of the bill in 1982; transportation, which accounted for 7 percent of that bill; fuels and electricity, which accounted for 5 percent; corporate profits, which accounted for 6 percent; and other items including

Table 2.—Components of the Marketing Bill for U.S. Farm. Produced Foods, 1971-82 (in billions)

Year	Labor[a]	Packaging materials	Intercity transportation rail and truck	Fuels and electricity	Corporate profits before taxes	Other[b]	Total marketing bill[c]
1971	$34.5	$8.5	$6.0	$ 2.4	$3.9	$23.2	$ 78.5
1972	36.6	8.9	6.1	2.5	4.0	24.3	82.4
1973	39.7	9.4	6.4	2.8	5.4	23.4	87.1
1974	44.3	11.8	7.5	3.7	6.1	24.8	98.2
1975	48.7	13.5	8.5	4.6	7.5	30.6	113.4
1976	53.7	14.6	9.1	5.0	7.6	35.4	125.4
1977	58.4	15.2	9.8	5.6	8.0	37.3	134.3
1978 ...., . . .	65.3	16.3	10.3	6.2	9.0	37.8	144.9
1979	73.8	18.4	11.6	7.6	9.9	41.5	162.8
1980	80.7	21.1	12.7	9.0	11.0	45.2	179.7
1981	90,7	22.9	14,1	10.9	12.0	51.5	202,1
1982	97.2	23.2	14.7	11.2	12.9	55.3	214.5

[a]Includes employee wages or salaries, and their health and welfare benefits, Also includes imputed earnings of proprietors, partners, and family workers not receiving stated remuneration.

[b]Includes depreciation, rent, advertising and promotion, interest, property taxes and insurance, accounting and professional services, and many miscellaneous items. Data for 1987-89 also include fuels and electricity.

[c]The marketing bill is the difference between the farm value or payment to farmers for foodstuffs and consumer expenditures for these foods both at food stores and away from home eating places. Thus, it covers processing, wholesaling, transportation, and retailing costs and profits

SOURCE: U.S. Department of Agriculture, Economic Research Service, 1982 depreciation, advertising, interest, and repairs, which accounted for the remaining 26 percent of the marketing bill.

Contribution to the Output of the Food and Fiber System

As shown below, the total output of the U.S. food and fiber system continues to increase, and in 1981 was estimated at $612 billion (3). The nonfarm activities or marketing provides over 85 percent of the value added to the food and fiber system's output.

Year	output (in billions)	Percentage added by: Farming	Nonfarm activities
1978	$432.7	14%	86%
1979	486.2	15	85
1980	532.8	13	87
1981[a]	612.0	NA	NA

[a]Preliminary

Table 3.—Numbers of Establishments and Employees in Food Marketing Industries, 1967, 1972, 1977

Industry and year	Number of establishments	Number of employees
Manufacturers:		
1967	32,518	1,725,900
1972	28,184	1,663,000
1977	26,656	1,622,100
Wholesalers:		
1967	40,055	533,837
1972	38,531	579,531
1977	37,960	601,920
Food stores:		
1967	294,243	1,444,469
1972	267,352	1,722,486
1977	251,971	1,959,008
Eating places:		
1967	236,563	1,736,693
1972	253,136	2.317.425
1977	274,337	3,425,060

SOURCE: Census of Manufacturers, Wholesale Trade, and Retail Trade, 1977

Number of Food Marketing Establishments and Employees

Table 3 shows the numbers of establishments and employees in food marketing industries (food manufacturing, food wholesaling, food stores, and eating places) for the years 1967, 1972, and 1977. From 1967 to 1977, both the number of food manufacturing establishments and the number of employees in such establishments declined, from 32,518 establishments and about 1.7 million employees in 1967 to 26,656 establishments and about 1.6 million employees in 1977.

During the same period, the number of food wholesaling establishments and food stores also declined, but in these establishments, the number of employees increased. The increase in the number of employees in food stores from 1967 to 1977 was substantial, from 1.4 million employees in 1967 to about 2 million employees in 1977.

Of all the establishments shown in table 3, only eating places increased in number from 1967 to 1977. Along with the increase in number of establishments, there was a substantial increase in the number of employees in eating places. In 1967, eating places employed about 1.7 million people; by 1977, the number of employees had reached about 3.4 million.

Consumption of Energy

According to the Department of Energy, an estimated 17 percent of the total energy consumed in the United States is consumed by the U.S. food and agricultural system, which includes production, marketing, and consumption (4). About half of this, or nearly 8 percent of the total, is consumed by the food marketing sector. This includes 4.4 percent for processing, 2.1 percent for transportation, 0.5 percent for wholesaling, and 0.8 percent for retailing. The production of food accounts for 3 percent of the total energy consumed, and consumption at home accounts for the remaining 6 percent.

IMPACT OF THE FOOD MARKETING SECTOR ON THE U.S. ECONOMY

The food marketing sector has a number of significant impacts on the U.S. national economy, and these are described further below. On the negative side, the food marketing sector has been a major contributor to inflation in the general economy. It has also contributed to lagging productivity. On the positive side, however, the food marketing sector contributes significantly both to the gross national product (GNP) and employment. Increased output in food manufacturing has a large impact on other sectors of the economy (3). And too, food is a significant component of U.S. import-export trade.

Contribution to Inflation

Over the past decade, there has been a significant increase in consumer prices, and inflation in consumer food prices has had a profound effect on the national economy. The annual rate of inflation in consumer food prices for the years 1951 through 1981, as well as the proportion of overall inflation accounted for by inflation in consumer food prices for those years, is shown in table 4. During the 1970's, food price inflation averaged 8 percent per year and accounted for an average of 26 percent of inflation in the general economy.

Table 4.—Contribution of Food Prices to Inflation, 1951-81

Year	Overall inflation rate (percent)	Food price inflation rate (percent)	Contribution of food prices to overall inflation (percentage points)	Proportion of overall inflation accounted for by food price inflation (percent)
1951	7.9%	11.1%	2.7	34.20/o
1952	2.2	1.0	0.4	18.2
1953	0.8	– 1.5	–0.4	–33.3
1954	0.5	–0.2	–0.1	–16.7
1955	–0.4	– 1,4	0.3	–75.0
1956	1.5	0.7	0.2	13.3
1957	8.6	3.3	0.8	22.2
1958	2.9	4.2	1.0	34.5
1959	0.8	– 1.6	–0.4	–33.3
1980	1.5	1.0	0.2	13.3
1961	1.1	1.3	0.3	27.3
1962	1.2	0.9	0.2	16.6
1963	1.3	1.4	0.3	23.1
1964	1.4	1.3	0.3	21.4
1965	1.5	2.2	0.5	33.3
1966	3.2	5.0	1.2	37.5
1987	2.8	0.9	0.2	7.1
1988	4.4	3.6	0.9	20.5
1989	5.7	5.1	1.2	21.1
1970	6.1	5.5	1.3	21.3
1971	4.3	3.0	0.7	16.3
1972	3.4	4.3	1.0	29.4
1973	6.1	14.5	3.5	57.4
1974	9.8	14.4	3.5	35.7
1975	9.1	8.5	2.0	22.0
1976	5.6	3.1	0.8	14.3
1977	6.3	6.3	1.5	23.8
1978	7.8	10.0	1.8	23.1
1979	10.0	10.9	2.0	20.0
1980	13.8	8.6	1.5	10.9
1981	9.2	8.2	1.4	15.2

[a]The proportion of overall inflation accounted for by food price inflation is derived by dividing the contribution of food prices to overall inflation by the overall Inflation rate.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, as presented by R. D. Knutson, J. B. Penn, and W. T. Boehm in *Agricultural and Food Policy (New* Jersey: Prentice-Hall, Inc., January 1983).

Food price inflation peaked at 14.5 percent and 14.4 percent in the years 1973 and 1974, respectively, and it accounted for nearly 50 percent of the inflation in the general economy during those 2 years.

Table 5 shows that much of the inflation in food prices is due to increases in the farm-to-retail price spread —i. e., marketing, The inflationary impact of the food marketing sector was especially great in the years 1974, 1975, 1976, 1978, 1979, 1980, and 1981. In 1981, for example, increases in the farm-to-retail price spread accounted for 74 percent of the increases in food prices at food stores.

From 1971 to 1981, consumer expenditures on food rose about $170 billion (from $114.6 billion in 1971 to $285 billion in 1981), and increases in the marketing bill have accounted for 73 percent of that amount (3). In some years, even though farm prices declined, consumer food prices increased because of increases in the food marketing sector. Labor and energy have been major components of these increases.

Contribution to Lagging Productivity

Historically, productivity gains in the food marketing sector have been less dramatic than those achieved in farming. Most components of the food manufacturing and distribution sectors (see table 6) are afflicted with laggard or declining growth. The problem is especially evident in the food transportation, food retailing, food service, and some food manufacturing industries.

Labor productivity growth rates in the food manufacturing sector vary considerably by industry. Although increases in labor productivity growth rates have occurred since 1972 in some industries (e. g., wet corn milling and soft drink manufacturing), in other industries (e. g., meatpacking, sugar, candy, and breakfast cereal), there have been no significant increases; in one industry (i.e., blended flour), productivity has actually declined.

In the food distribution sector, labor productivity growth rates in the rail and truck transportation have not increased significantly since 1972. In retail food stores and in eating and drinking places, productivity now is significantly below 1958-72 levels. Lagging productivity growth in the food processing and distribution sectors, in addition to contributing to lagging productivity in the general economy, has contributed to increased rates of food price inflation (2).

Contribution to Gross National Product

The U.S. food and fiber system in 1980 accounted for about 20 percent of the GNP. According to USDA, 87 percent of that (17.8 percent of total GNP) was attributable to nonfarm or market industries: 38 percent was attributable to retailing, wholesale trade, and transportation industries; 31 percent was attributable to processing and manufacturing industries; and 18 percent was attributable to services and raw materials industries (3).

Table 5.—Contribution of Food-Price Components to Price Increases at Food Stores, 1971-81

Year	Change in food store prices due to:			Total retail price increase (percent)
	Farm value of food (percentage points)	Farm to retail price spread (percentage points)	Fish and imported foods (percentage points)	
1971	0.1	1.5	0.8	2.4
1972	3.0	1.3	0.2	4.5
1973	11.6	3.7	1.0	16.3
1974	3.2	9.2	2.5	14.9
1975	1.3	5.1	1.9	8.3
1976	– 1.8	2.7	1.2	2.1
1977	0.1	1.8	4.1	6.0
1978	4.5	4.6	1.4	10.5
1979	3.4	6.2	1.2	10.8
1980	1.7	4.2	2.1	8.0
1981	0.9	5.4	1.0	7.3

SOURCE Derived from Bureau of Labor Statistics data and USDA market basket statistics.

Table 6.—Productivity Growth Rates for the U.S. Food Manufacturing and Distribution Sectors: 1958-72 Compared With 1973-79

	Annual productivity growth rate (output per man hour)		Direct ion of change
	1958-72 (percent)	1973-79 (percent)	
Food manufacturing:			
Fluid milk	3.8%	3.5%	Reduction
Preserved fruits and vegetables	2.7[a]	1.9[d]	Reduction
Flour and other grain products	4.1[a]	4.9	Increase
Cereal and breakfast foods	2.2[c]	0.8[d]	Reduction
Rice milling	3.6[c]	2.5[d]	Reduction
Blended and prepared flour	2.9	–4.0[d]	Negative
Wet corn milling	4.O[c]	9.8[d]	Increase
Prepared feed ... ,	4.4[c]	2.2[d]	Reduction
Raw and refined cane sugar	3.5	1.5[d]	Reduction
Beet sugar	3.4	0.6[d]	Reduction
Candy and confectionery products	3.6[a]	0.2[d]	Reduction
Malt beverages	5.9[a]	5.3	Reduction
Distribution:			
Intercity trucking[e]	2.6[c]	1.1[d]	Reduction
Intercity trucking[e] (general freight)	2.1[c]	1.4[d]	Reduction
Railroad (car miles)	3.8[a]	0.8	Reduction
Bakery products	2.7[b]	1.0	Reduction
Retail food stores	3.0	– 1.0	Negative
Eating and drinking places	1.2	– 2.4	Negative

[a]1954-72.
[b]1957-72.
[c]1963-72.
[d]1973-78.
[e]Output per employee.

SOURCE: B. R. Eddleman, L. Teigen, and J. C. Purcell, "Productivity in U.S. Food and Agriculture: Implications for Research and Education," paper presented at the Southern Agricultural Economics Association meeting, Orlando, Fla., February 1962, p. 6a.

Contribution to Employment

In 1980, the U.S. food and fiber system accounted for approximately 23 percent of total employment in the country, a percentage which is roughly the same as the food and fiber system's contribution to GNP. The number of employees is shown in table 7. In 1980, 20.4 million (about 86 percent) of the 23.7 million people employed in the food and fiber system as a whole were employed in nonfarm industries (i.e., food processing, resources and services, manufacturing, transportation, trade, retailing, and eating establishments). Over the years, the number of employees in farming has declined, while the number employed in the food marketing sector has increased (see table 7).

Table 7.—Employment in the U.S. Food and Fiber System, 1978, 1979, 1980

Food and fiber system activity	Number of employees (in millions)		
	1978	1979	1980
Production agriculture	3.4	3.4	3.3
Non-farm	19.0	20.1	20.4
Food processing	1.7	1.7	1.7
Resources and services	2.3	2.5	2.5
Manufacturing	4.7	5.0	5.1
Transportation, trade, and retailing	7.2	7.6	7.7
Eating establishments	3.1	3.3	3.4
Total employment in the U.S. food and fiber system	22.4	23.5	23.7
Total employment in the U.S. economy[a]	100.4	102.9	104.7
Employment in the food and fiber system as a percent of the U.S. employment	22.30/o	22.80/o	22.60/o

[a]Represents the available work force,

SOURCE: U.S. Department of Agriculture, Economic Research Service, 1982,

Income Multiplier for Food Manufacturing

The impact of the food marketing system on the U.S. economy can also be viewed through the income multipliers that are derived from input/output analysis for the United States. The income multiplier for a particular sector of the economy is a measure of the increase in income to the whole economy resulting from an increase in output by that particular sector.

Because of the food manufacturing industry's heavy reliance on other industries for inputs, its high level of labor utilization, and its operation on a comparatively low profit margin, the income multiplier for food manufacturing is much greater than the income multiplier for other sectors of the economy (3). The weighted average personal income multiplier for food manufacturing is 9.8 (this compares to a multiplier of 4.8 for nonfood and nonfiber manufacturing, 4.0 for mining, 3.5 for services, 3.4 for transportation and housing, and 2.8 for wholesale and retail trade). This implies that a $1 million increase in output or income in the food manufacturing sector would lead to a $9.8 million increase in income in the total economy, while the total impact would be less than $5 million for a $1 million increase in income to those employed in other manufacturing.

Contribution to International Trade

Food represented about 19 percent of the total U.S. export trade in 1982 and 7 percent of the U.S. import trade. These figures are representative of the food production and marketing sectors' combined contribution to international trade over the past 15 years (3).

As shown below, the agricultural sector has provided a positive trade balance which reached a high of $24 billion in 1981, In contrast, the nonagricultural sector has a growing negative trade balance which increased to $53 billion by 1981.

U.S. Trade Balance, 1975-82(billions)

	Agricultural	*Nonagricultural*	*Total*
1975 ....., . . .	$12.57	–$ 2.83	$ 9.74
1976 .	12.01	–20.67	–8.67
1977	10.20	–39.97	– 29.78
1978 . .	14.58	–46.38	– 31.80
1979 . .	18.02	–45.37	–27.35
1980	23.89	–47.24	–23.35
1981	24.35	–53.52	–29.17
1982	19.73	– 52.64	–32.91

SOURCE: U.S. Department of Agriculture, Economic Research Service, 1982

The principal agricultural exports are the basic commodities of wheat, corn, and soybeans. With the exception of soybean oil and soybean meal, few value-added agricultural products are exported.

CHAPTER 2 REFERENCES

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Chapter 3

Investment in Postharvest Technology and Marketing Economics Research

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Chapter 3

Investment in Postharvest Technology and Marketing Economics Research*

Public food and agricultural research in the United States is conducted chiefly by the U.S. Department of Agriculture (USDA) and State agricultural experiment stations (SAES) in conjunction with land-grant universities (including the 1890 Institutions and Tuskegee Institute).** USDA research is funded from Federal sources. SAES research is supported by Federal funds, State appropriations and sales, and grants from private sources.

Historical data are available for public expenditures on food and agricultural research, including postharvest technology and marketing economics (PHTME) research, and are presented in the analysis below. Patterns and trends in USDA and SAES expenditures are analyzed for the 16-year period from 1966 to 1981.

For the analysis of public expenditures, agricultural research is separated into three components: 1) production, 2) PHTME, and 3) other. Production research includes research on all aspects of producing crops and livestock. PHTME research encompasses research on all functions after harvest of crops and beginning with the first phase of marketing for livestock. Thus, it includes all functions from storage to distribution of agricultural products through the institutional food trade and wholesale and retail outlets. "Other" food and agricultural research includes all remaining publicly funded research (rural development, human nutrition, conservation of resources, environment, etc.). The "other" category is a residual category that includes all research that is neither production oriented nor PHTME. The particular research problem areas included in PHTME are identified in appendix A.

The scope and amount of food and agricultural research performed by private industry cannot be reported accurately, because reliable data are lacking. Private firms engaged in agricultural research are not required to identify themselves, nor are they required to disclose their investments in agricultural research publicly. Thus, any analysis of agricultural research by private industry is based on incomplete data. The data that are available will be discussed later in this chapter.

*The material found in this chapter was originally prepared by Joseph Havlicek, Jr., and Daniel Otto, and can be found in more detail in their paper, "Historical Analysis of Investment in Food and Agricultural Research, " OTA, An *Assessment of the United States Food and Agricultural Research System, Vol. II—Commissioned Papers,* Part C, April 1982,

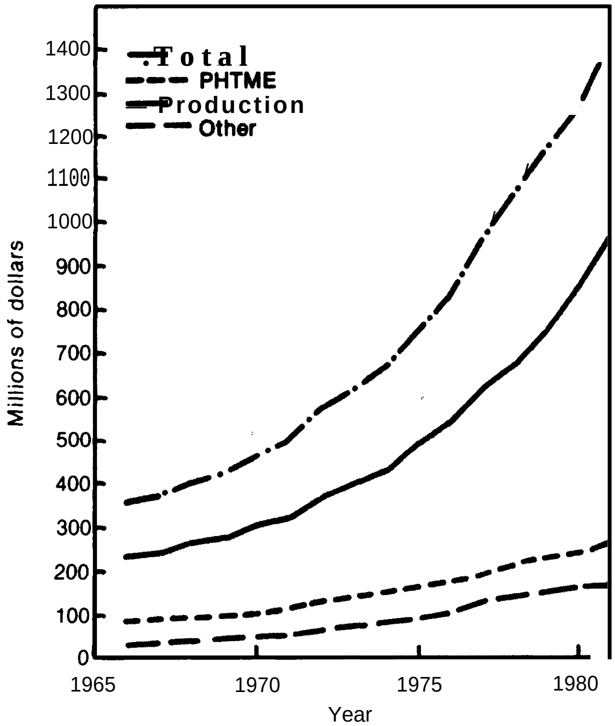
**A description of the U.S. food and agricultural research system can be found in An *Assessment of the United States Food and Agricultural Research System* (2).

USDA AND SAES EXPENDITURES ON PRODUCTION, PHTME, OTHER, AND TOTAL AGRICULTURAL RESEARCH, 1966-81

USDA and SAES expenditures on production, PHTME, other, and total agricultural research for the 16-year period from 1966 through 1981 are presented in figure 1, and constant dollar expenditures are shown in figure 2.* Production research is a much larger component of total public agricultural research than PHTME research is. Production research accounted for 69 percent of total USDA/SAES research in 1981. Furthermore, combined USDA and SAES expenditures on production research, in current and constant dollars, exhibit patterns almost identical to those of combined expenditures on total agricultural research. From 1966 to 1981, current dollar USDA and SAES expenditures on production research increased steadily. The current dollar increase during this period was 306 percent, equivalent to a 38-percent increase in constant dollars.

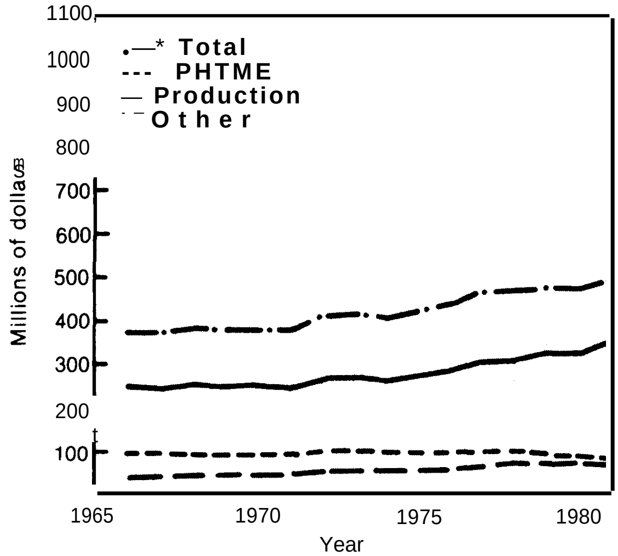
'Data used to construct these and all remaining figures in this chapter can be found in app. C.

Figure 1.—Combined USDA/SAES Expenditures on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in current doiiars)



SOURCE, Off/cc of Technology Assessment.

Figure 2.—Combined USDA/SAES Expenditures on Production, PHTME, Other, and Totai Agricultural Research, 1966-81 (in constant dollars)



SOURCE: Office of Technology Assessment

Public expenditures on PHTME research accounted for about 24 percent of total public agricultural research funds in 1966 and for approximately 18 percent in 1981. In current dollars, combined USDA and SAES expenditures on PHTME research steadily increased from 1966 to 1981, but the 198-percent increase in current dollars represented a 1.6-percent overall increase in constant dollars. Between 1966 and 1978, there was an increase of approximately 9.6 percent in constant dollars for PHTME research. However, from 1978 to 1981, constant dollar expenditures for PHTME research declined approximately 8 percent.

"Other" food and agricultural research, the smallest of the three components of public research, in current dollars rapidly increased from 1966 to 1978 but declined from 1978 to 1981. In current dollars, the overall increase during the 1966-81 period was 425 percent, representing a 79-percent increase in constant dollars.

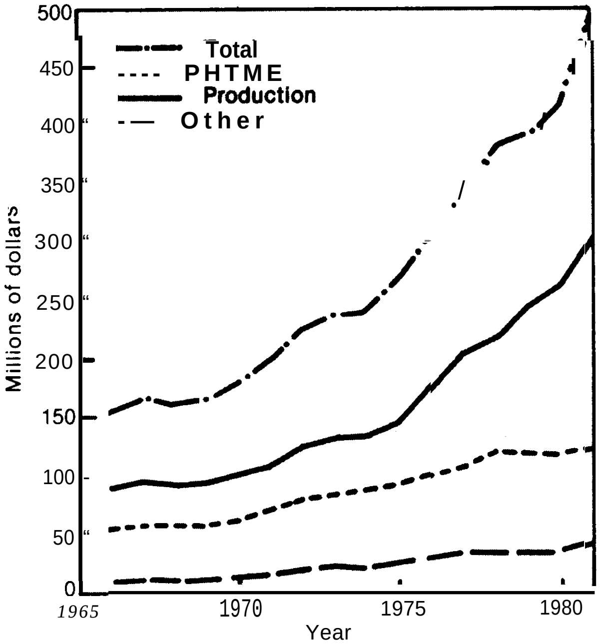
USDA Expenditures

USDA expenditure patterns for production, PHTME, other, and total agricultural research for the period from 1966 to 1981 are almost identical to combined USDA/SAES expenditure patterns, as shown in figures 3 and 4.

USDA expenditures for production research, the largest component of USDA research, accounted for 64 percent of total USDA research expenditures in 1981. USDA expenditures on production research increased 251 percent in current dollars from 1966 to 1981, but increased about 20 percent in constant dollars.

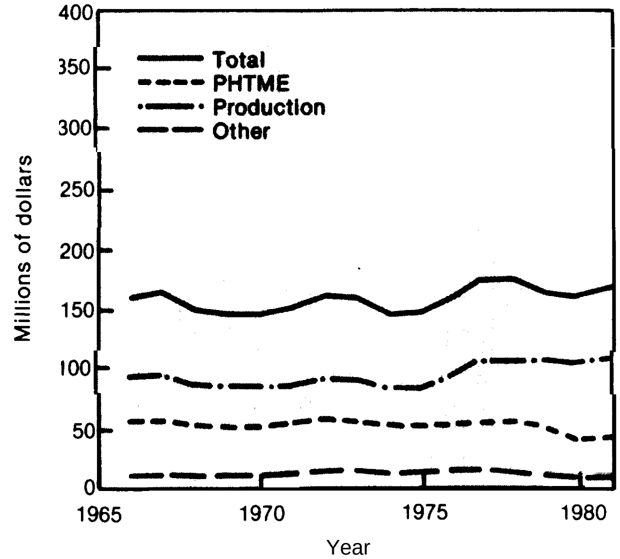
USDA expenditures on PHTME research increased 144 percent in current dollars from 1966 to 1981, but decreased by 17 percent in constant dollars. Much of this decrease in constant dollar expenditures occurred from 1979 to 1981, partly because of level current dollar funding but also because of the rate of inflation. As a proportion of total USDA research expenditures, PHTME expenditures decreased from 35 percent in 1966 to 27 percent in 1981.

Figure 3.—USDA Expenditures on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in current dollars)



SOURCE. Off Ice of Technology Assessment

Figure 4.—USDA Expenditures on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in constant dollars)



SOURCE: Office of Technology Assessment

From 1966 to 1981, USDA expenditures on "other" research increased 293 percent in current dollars and 34 percent in constant dollars. Despite these increases, however, other research is still a small component of total agricultural research in USDA and in 1981 accounted for only 9 percent of the total.

SAES Expenditures

SAES expenditures on production, PHTME, other, and total agricultural research for the 16-year period from 1966 to 1981 are shown in current and constant dollars in figures 5 and 6, respectively. These figures show that SAES expenditure patterns are similar to those for USDA.

Production research is the largest component of total SAES research, and during the 1966-81 period, current dollar expenditures increased 338 percent, although constant dollar expenditures increased by 50 percent. SAES expenditures on PHTME research were of approximately the same magnitude as SAES expenditures on "other" research-but for "other" research, current and constant dollar expenditures increased 488 and 100 percent, respectively, while for PHTME research, current dollar expenditures increased 287 percent and constant dollar expenditures by 32 percent. SAES expenditures on PHTME research decreased from 16 percent of total SAES research funds in 1966 to 14 percent in 1981. The proportion of SAES expenditures devoted to "other" research increased from 11 percent of total SAES research expenditures in 1966 to 15 percent in 1981, but was as high as 17 percent in 1978.

SAES/USDA Relative Shares of PHTME and Total Agricultural Research

Expenditures by SAES on PHTME and total agricultural research as a percent of combined USDA/SAES expenditures on such research for the period from 1966 to 1981 are presented in figure 7. With some minor variations, the SAES proportion of combined USDA/SAES expenditures on all agricultural research increased from a low of 56 percent in 1967 to a high of 65 percent in 1981. At no time during the 1966-81 period did SAES account for less than half the combined USDA/SAES expenditures for all agricultural research.

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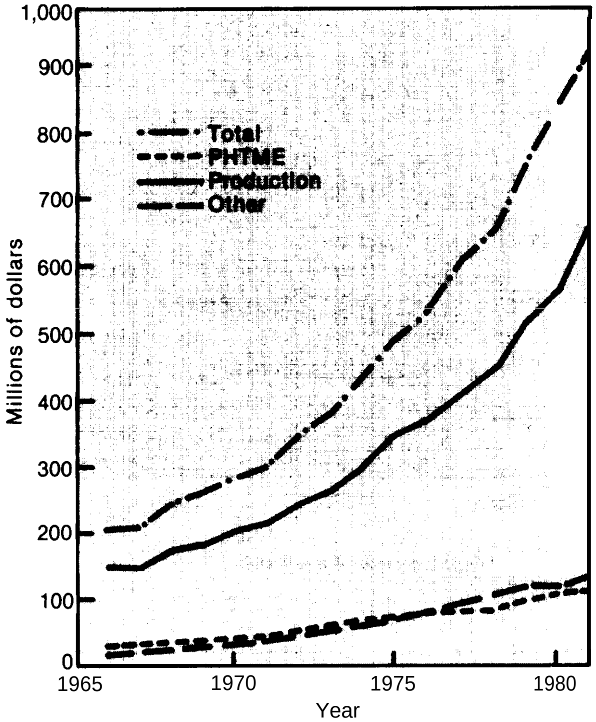
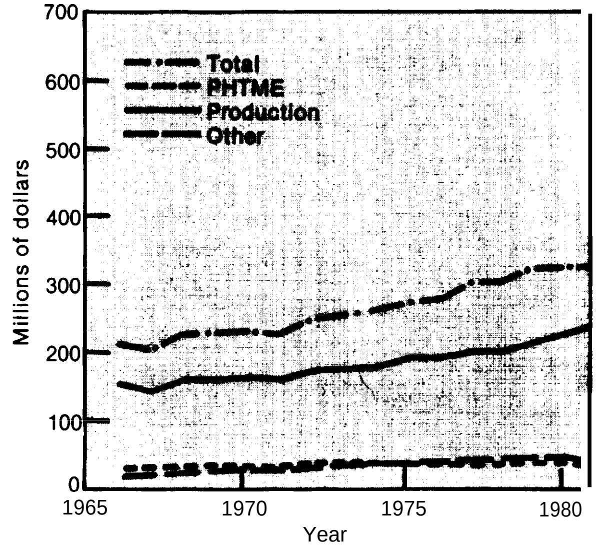
Figure 5.–SAES Expenditures on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in current dollars)



SOURCE: Office of Technology Assessment.

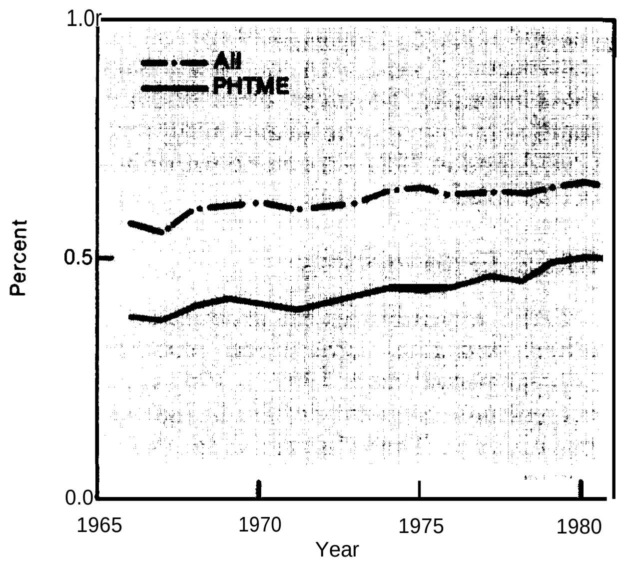
Figure 6.–SAES Expenditures on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in constant dollars)



SOURCE: Off Ice of Technology Assessment.

SAES expenditures on PHTME research as a percent of total public expenditures on PHTME research increased about 14 percent during the 1966-81 period. Although there was a slight variation, the proportion increased from about 37 percent in 1967 to 51 percent in 1980.

Figure 7.—SAES Expenditures on PHTME and on Total Agricultural Research as a Percent of Combined USDA/SAES Expenditures on PHTME and Total Agricultural Research, 1966-81



SOURCE: Off Ice of Technology Assessment,

USDA and SAES Expenditures on PHTME and Total Research for Selected Commodities

Patterns in expenditures by USDA and SAES on PHTME and total research were analyzed for the 16-year period from 1966 to 1981 for nine selected agricultural commodities: potatoes, other vegetables, corn, wheat, soybeans, rice, cotton, dairy products, and beef. The analysis is presented in detail in appendix B.

The expenditures of SAES and USDA on total and PHTME research for the nine commodities exhibited several unique patterns in terms of levels and variations in funding. However, some general tendencies did exist which allowed the following general conclusions to be drawn:

1. In general, the total expenditures on all research for specific commodities were greater in SAES than in USDA except for cotton.

2. While current dollar total research expenditures by both SAES and USDA for all commodities increased from 1966 to 1981, the constant dollar expenditures exhibited slight or no increases and for some commodities declined substantially.
3. The loss of purchasing power due to inflation from 1966 to 1981 was substantial, and the real dollars available for total agricultural research on the nine commodities in both SAES and USDA remained at about the same level over the 16-year period.
4. In general, the level and proportion of expenditures allocated to PHTME research on these commodities were greater in USDA than in SAES.
5. From 1966 to 1981, both SAES and USDA current dollar expenditures for PHTME research on all nine commodities exhibited an overall increase, but current dollar expenditures for PHTME research for several commodities decreased from 1977 to 1979.
6. From 1966 to 1981, both SAES and USDA constant dollar expenditures for PHTME research on the nine commodities only increased slightly or declined.
7. PHTME commodity research generally declined more in USDA than in SAES during this 16-year time period.
8. SAES did not increase commodity PHTME research enough to make up for the USDA decline.

PRIVATE INDUSTRY EXPENDITURES ON APPLIED RESEARCH AND DEVELOPMENT OF AGRICULTURAL CHEMICALS, FARM MACHINERY, FOOD, AND KINDRED PRODUCTS, 1963-75

Data are not available on agricultural research expenditures by private industry to permit separating out production, PHTME, and other food and agricultural research. Data available for private industry pertain to applied research and development in agricultural-related products: agricultural chemicals, farm machinery, and food and kindred products.

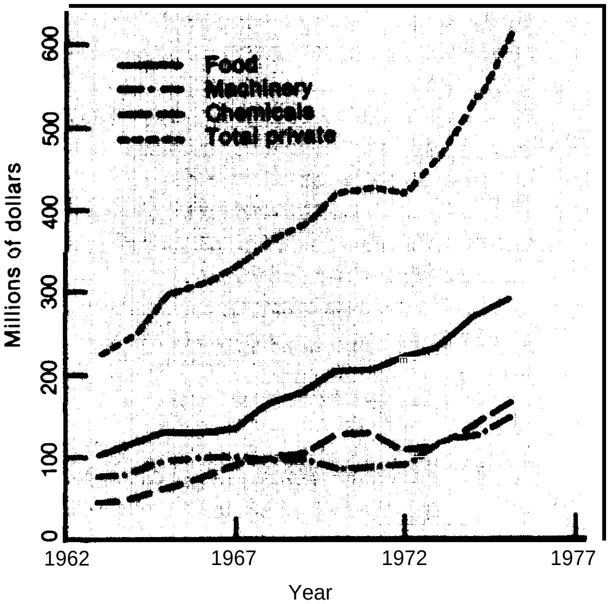
Much of private industry's applied research and development in agricultural chemicals and farm machinery tends to be production-oriented. In the following discussion, it is assumed that private industry's applied research and development on food and kindred products in private industry is similar in nature to the PHTME research in the public sector. This assumption allows some comparisons of trends in public and private expenditures on PHTME research,

Expenditures by private industry on applied research and development of agricultural chemicals, farm machinery, and food and kindred products for the period 1963 to 1975 are presented in current dollars in figure 8 and in constant dollars in figure 9. The largest of these three components of private industry's applied research and development—and the only one for which there was a steady increase in both current and constant dollar expenditures in the period 1963 to 1975—was applied research and development of food and kindred products. From 1963 to 1975, private industry expenditures on applied research and development of food and kindred products increased by 186 percent in current dollars and by 47 percent in constant dollars. These expenditures accounted for nearly half the total private industry expenditures on applied research and development of agricultural-related products.

Current dollar expenditures by private industry for applied research and development of farm machinery, while exhibiting an erratic pattern during the 1963-75 period, overall increased about 91 percent. Most of the erratic fluctuations occurred between 1967 and 1972. Constant dollar expenditures in this area exhibited considerable fluctuation, decreasing by 2 percent from 1963 to 1975 and by 15 percent from the high in 1965 to 1975.

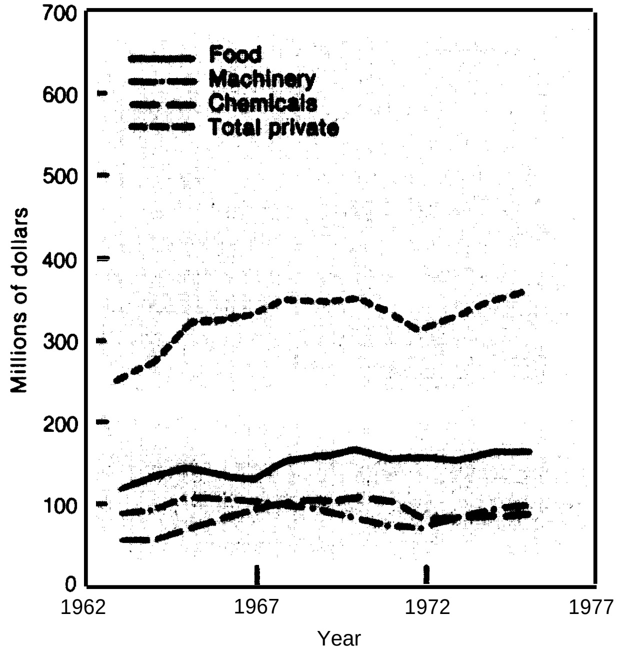
Current dollar expenditures by private industry for applied research and development of agricultural chemicals steadily increased from 1963 to 1975, except in 1972 and 1973. The overall increase was about 267 percent. The constant dollar expenditures varied over the 1963-75 period, but overall increased about 88 percent.

Figure 8.—Private industry Expenditures on Appiied Research and Development of Agricuiturai Chemicals, Farm Machinery, and Food and Kindred Products, 1963-75 (in current doiiars)



SOURCE: Office of Technology Assessment,

Figure 9.—Private industry Expenditures on Appiied Research and Development of Agricuiturai Chemicais, Farm Machinery, and Food and Kindred Products, 1963-75 (in constant dollars)



SOURCE: Office of Technology Assessment.

Finally, private industry expenditures on applied research and development of food and kindred products ranged from 150 percent of combined USDA / SAES expenditures on PHTME research in 1966 to 176 percent of these expenditures in 1975. During that lo-year period, the expenditures by private industry on applied research and development of food and kindred products increased more rapidly than did the expenditures by USDA and SAES on PHTME research.

USDA EXPENDITURES ON PRODUCTION, PHTME, OTHER, AND TOTAL AGRICULTURAL RESEARCH BY RESEARCH AGENCY, 1966-81

Patterns in expenditures on production, PHTME, other, and total agricultural research for the major research agencies within USDA are analyzed in this section for the 16-year period from 1966 to 1981. The agencies considered are the Agricultural Research Service (ARS) and the Economic Research Service (ERS). For the Agricultural Marketing Service (AMS), comparable data are not available during this time period. *

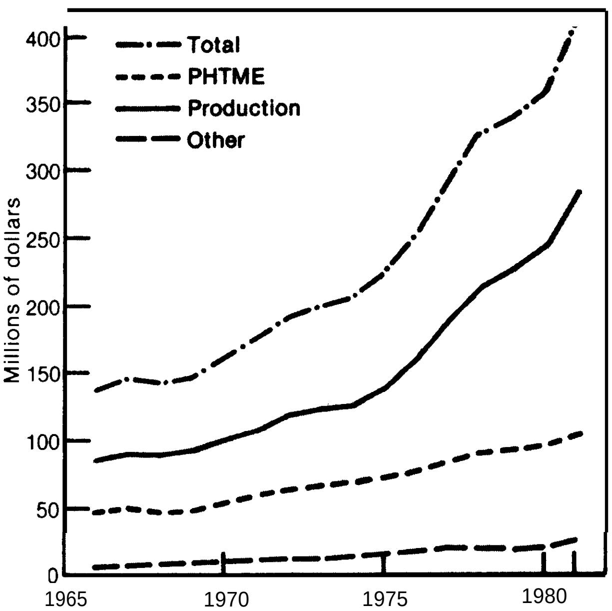
Agricultural Research Service Expenditures

Current dollar and constant dollar expenditures on production, PHTME, ** other, and total agricultural research by ARS for the 1966-81 period are presented in figures 10 and 11, respectively. In terms of total agricultural research funding, ARS was by far the largest service in USDA during this time.

*Research expenditures by Agricultural Marketing Service for other years are in table C-8 in app. C.

*● PHTME research supported by ARS is considered postharvest technology research as defined in ch. 2.

Figure 10.—ARS Expenditures on Production, PHTME[a], Other, and Total Agricultural Research, 1966-81 (in current dollars)



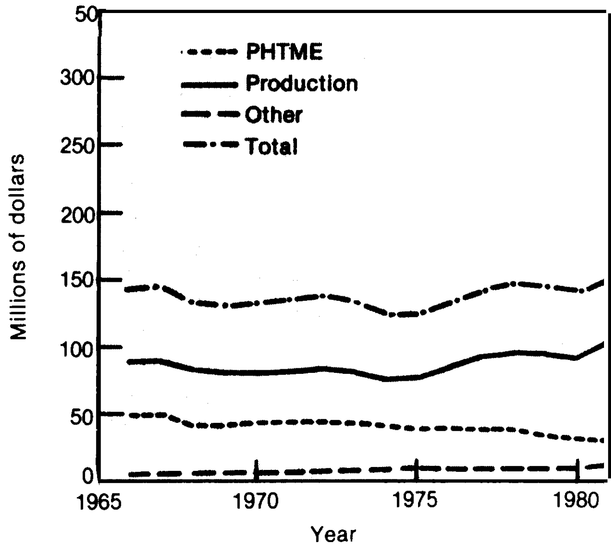
[a]PHTME research supported by ARS is considered postharvest technology research as defined in ch. 2

SOURCE Office of Technology Assessment

From 1966 to 1981, ARS current dollar expenditures on all agricultural research increased 207 percent. In 1966, ARS current dollar expenditures on all agricultural research were about $137 million, and these expenditures increased to approximately $419 million in 1981. Constant dollar ARS expenditures on all agricultural research from 1966 to 1981 exhibited considerable year-to-year fluctuation. They decreased from $144 million in 1966 to $135 million in 1976, then increased to $150 million in 1978, again decreased in 1979 and 1980, and finally increased to the $150 million level in 1981.

From 1966 to 1981, production research constituted the largest part of total agricultural research funding in ARS. The pattern of ARS expenditures on production research during that period is similar to that of ARS total agricultural research expenditures. ARS current dollar expenditures on production research increased fairly steadily throughout the 1966-81 period. These expenditures were about $85 million in 1966 and increased by 235 percent to $286 million in 1981. Constant

Figure 11 .—ARS Expenditures on Production, PHTME[a], Other, and Total Agricultural Research, 1966-81 (in constant dollars)



[a]PHTME research supported by ARS is considered postharvest technology research as defined In ch. 2,

SOURCE: Office of Technology Assessment.

dollar expenditures on production research by ARS fluctuated from 1966 to 1981, but increased by 14 percent overall, from about $89 million in 1966 to $102 million in 1981.

ARS current dollar expenditures on PHTME research, after a slight decrease from 1967 to 1968, steadily increased from about $46 million in both 1966 and 1968 to $107 million in 1981. In constant dollars, ARS expenditures on PHTME research exhibited some variation, but decreased by 20 percent overall from 1966 to 1981.

The remaining component of ARS agricultural research, the category labeled "other," has been a small component of ARS research expenditures. The current and constant dollar expenditures steadily increased from 1966 to 1978, but in constant dollars, decreased by nearly $10 million from 1978 to 1979. In current dollars, ARS expenditures on "other" research were a little over $5 million in 1966 and increased to nearly $20 million in 1978. In constant dollars, ARS expenditures on other research increased from nearly $6 million in 1966 to over $9 million in 1978, and returned to that level of spending in 1981.

Economic Research Service Expenditures

Current dollar expenditures on production, PHTME, * other, and total agricultural research in ERS for the 1966-81 period are presented in figure 12, and constant dollar expenditures are presented in figure 13. ERS current dollar total research expenditures increased by 185 percent during this 16-year period, but constant dollar expenditures decreased by 3 percent. However, there was a severe decline of 15 percent in ERS constant dollar total research expenditures from 1966 to 1977.

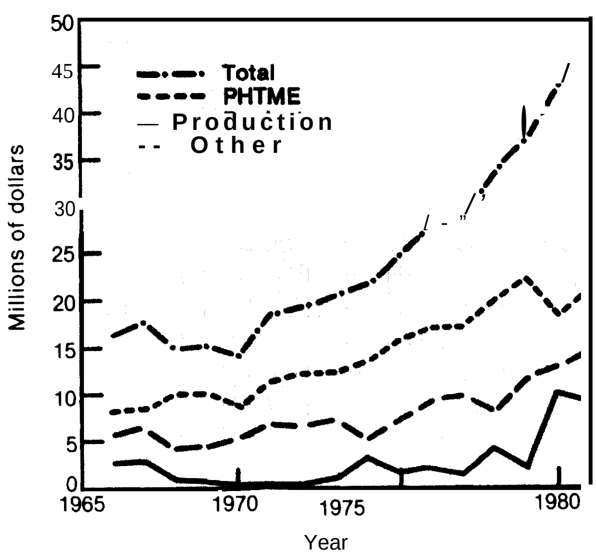
Expenditures on PHTME research were the largest component of total research expenditures in ERS. Expenditures on PHTME research in ERS, in both current and constant dollars, exhibit patterns similar to those for total agricultural research expenditures in ERS. From 1966 to 1981, ERS PHTME research expenditures increased 164 percent in current dollars but decreased by 10 percent in constant dollars.

*PHTME research supported by ERS is considered marketing economics research as defined in ch. 2.

Expenditures in ERS on "other" research varied substantially and from 1966 to 1981 show erratic patterns in both current and constant dollars. The overall increase from 1966 to 1981 in ERS current dollar expenditures on other research was 183 percent, while constant dollar expenditures decreased 3.5 percent. Throughout the 16-year period, expenditures on "other" research accounted for about one-third of the total research expenditures of ERS.

Expenditures on production research were the smallest component of total agricultural research expenditures in ERS. Expenditures on production research accounted for about 16 percent of total research expenditures in ERS during the early part of the 1966-81 period, but declined to a low of 2 percent in 1971. Thereafter, the proportion of ERS expenditures on production research varied, reaching 25 percent in 1980 but declining to 20 percent in 1979. Current dollar expenditures on production research in ERS increased 255 percent from 1966 to 1981, and constant dollar expenditures increased 21 percent.

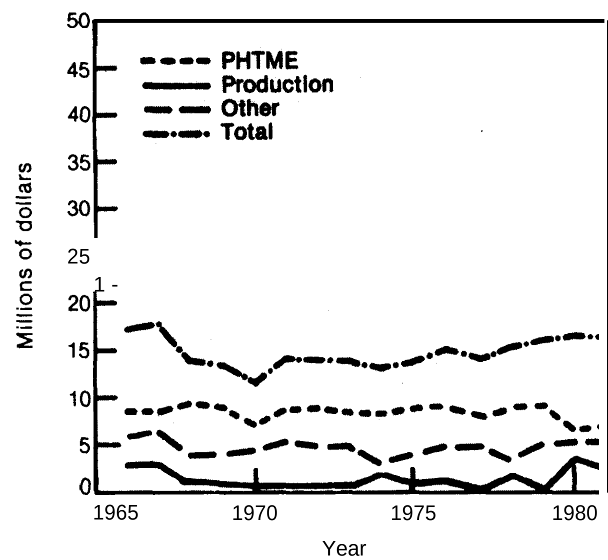
Figure 12.— ERS Expenditures on Production, PHTME[a], Other, and Total Agricultural Research, 1966-81 (in current dollars)



[a]PHTME research supported by ERS is considered marketing economics research as defined in ch. 2.

SOURCE. Office of Technology Assessment.

Figure 13.—ERS Expenditures on Production, PHTME[a], Other, and Total Agricultural Research, 1966-81 (in constant dollars)



[a]PHTME research supported by ERS is considered marketing economics research as defined in ch. 2

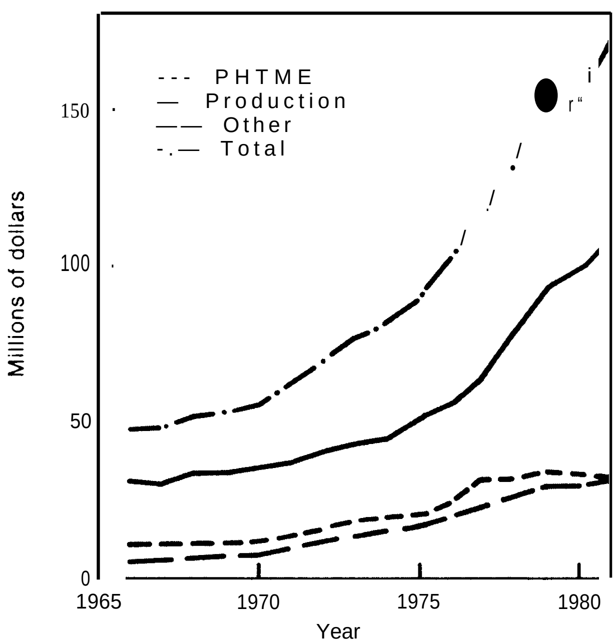
SOURCE. Office of Technology Assessment

SAES EXPENDITURES ON PRODUCTION, PHTME, OTHER, AND TOTAL AGRICULTURAL RESEARCH BY SOURCE OF FUNDS, 1966-81

Trends in SAES expenditures on production, PHTME, other, and total agricultural research for the period from 1966 to 1981 are analyzed below by the types or sources of funding: 1) Federal funds (including Hatch Act funds, USDA cooperative grants and agreements, other Federal sources); 2) State appropriations; and 3) private research funds to SAES.

A major trend in SAES funding is the decline of Federal support and the significant increases in State appropriations. The majority of funds for PHTME research in SAES now come from State appropriations. The analysis in this section shows that from 1966 to 1981, State appropriations increased from 43 to 56 percent of SAES funds for PHTME research, while Federal funds to SAES for PHTME research decreased from 53 to 38 percent.

Figure 14.—SAES Expenditures From Hatch Act Funds on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in current dollars)



SOURCE Office of Technology Assessment

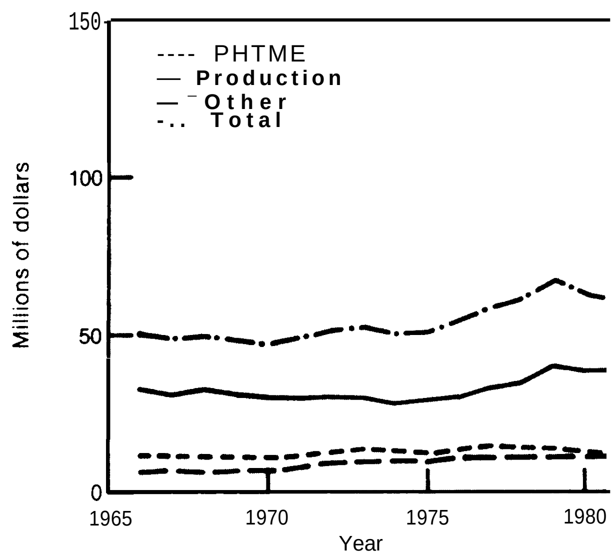
SAES Expenditures From Federal Funds

Hatch Act Funds

Current dollar expenditures on production, PHTME, other, and total agricultural research at SAES and the 1890 land-grant colleges and Tuskegee Institute from Hatch Act or Federal formula funds for the 1966-81 period are presented in figure 14, and constant dollar expenditures are given in figure 15. The total SAES expenditures on agricultural research from Federal formula funds steadily increased in current dollars from about $48 million in 1966 to nearly $172 million in 1981, an increase of 258 percent. Constant dollar expenditures varied during the 16-year period, but increased about 22 percent overall.

A large part of Federal formula funds (65 percent in 1966 and 1981) were allocated by SAES to production research. Current dollar expenditures on production research from formula funds increased 255 percent from 1966 to 1981, exhibiting a pattern similar to that of expenditures on total agricultural research from these funds. Con-

Figure 15.—SAES Expenditures From Hatch Act Funds on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in constant dollars)



SOURCE Off Ice of Technology Assessment

stant dollar expenditures on production research from Federal formula funds varied between $28 million and $42 million during the 16-year period, and increased 21 percent overall from 1966 to 1981.

SAES expenditures on PHTME research from Federal formula funds increased steadily in current dollars from about $11 million in 1966 to over $30 million in 1981, but declined slightly from 1979 to 1981. Overall, the increase in current dollar expenditures on PHTME research from 1966 to 1981 was 181 percent. However, SAES constant dollar expenditures on PHTME research decreased by 4 percent from 1966 to 1981. SAES expenditures on PHTME research accounted for 23 percent of SAES expenditures from Federal formula funds in 1966 and only 18 percent in 1981.

Current dollar expenditures from Federal formula funds on "other" agricultural research steadily increased from 1966 to 1981, declining slightly from 1979 to 1980. The overall increase from 1966 to 1981 was 413 percent. The corresponding increase in constant dollar expenditures was 75 percent. "Other" agricultural research was a relatively small part of SAES expenditures on agricultural research from Federal formula funds, ranging from 12 percent in 1966 to 19 percent in 1977, and then declining to 17 percent in 1981.

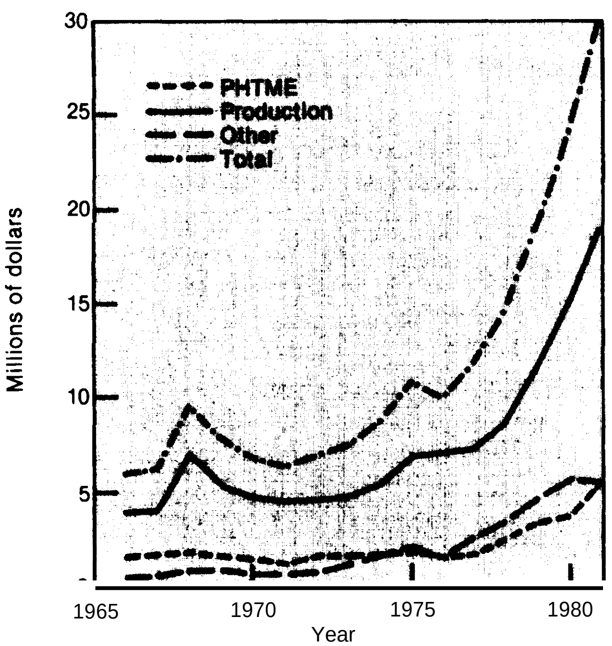
USDA Cooperative Grants and Agreements

Another Federal source of funding to the States is **cooperative grants and agreements with USDA. SAES current dollar expenditures on production, PHTME, other, and total agricultural research from cooperative grants and agreements for the 1966-81 period are presented in figure 16, and constant dollar expenditures** are given in figure 17.

From 1966 to 1981, SAES current dollar expenditures on total agricultural research from cooperative grants and agreements increased overall by 396 percent. The corresponding constant dollar expenditures increased 69 percent.

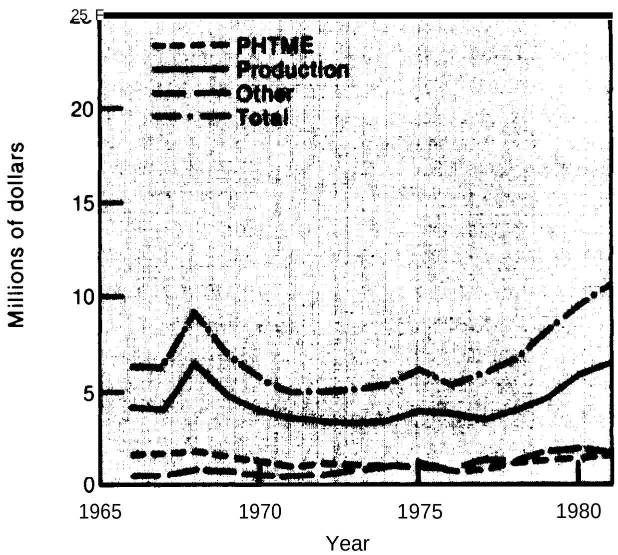
Expenditures on production research were the largest component of SAES expenditures from cooperative grants and agreements. In 1966, expenditures on production research comprised 65 percent of total research funds from cooperative

Figure 16.-SAES Expenditures From Cooperative Grants and Cooperative Agreements on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in current dollars)



SOURCE: Office of Technology Assessment.

Figure 17.-SAES Expenditures From Cooperative Grants and Cooperative Agreements on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in constant dollars)



SOURCE. Office of Technology Assessment

grants and agreements, and in 1981, they represented 63 percent. The patterns in SAES expenditures on production research, in current and constant dollars, are similar to those for SAES expenditures on total agricultural research from cooperative grants and agreements. In current dollars, the expenditures on production research increased 381 percent from 1966 to 1981. The corresponding increase in constant dollars was 64 percent.

SAES expenditures on PHTME research from cooperative grants and agreements varied in current dollars during the 1966-81 period, but increased by 251 percent overall. In constant dollars, the expenditures from cooperative grants and agreements on PHTME research increased 14 percent from 1966 to 1981. However, these expenditures decreased by 22 percent between 1966 and 1979. SAES expenditures on PHTME research as a percent of total SAES expenditures on agricultural research from cooperative grants and agreements decreased from 26 percent in 1966 to 18 percent in 1981.

SAES current dollar expenditures from cooperative grants and agreements on “other” agricultural research increased from about $0.5 million in 1966 to $5.5 million in 1981. In constant dollars, this increase was 257 percent. However, other research expenditures have been a small component of total SAES agricultural research expenditures from cooperative grants and agreements and increased from about 9 percent in 1966 to 18 percent in 1981.

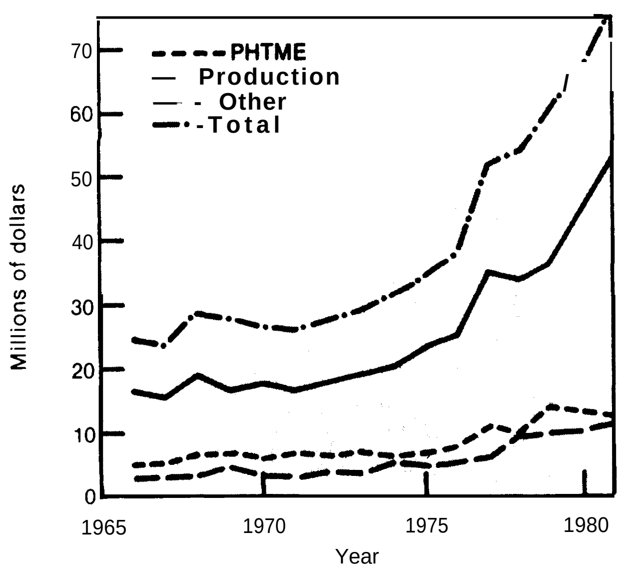
Other Federal Sources

The other Federal category includes obligations of funds reserved by SAES from contracts, grants, and cooperative agreements with Federal agencies other than USDA. SAES expenditures on production, PHTME, other, and total agricultural research from other Federal sources are presented in current and constant dollars for the 1966-81 period in figures 18 and 19, respectively.

SAES total agricultural research expenditures from other Federal sources exhibited some variation from 1966 to 1981, but current dollar expenditures increased by 217 percent overall. In constant dollars, the total expenditures increased by 8 percent from 1966 to 1981.

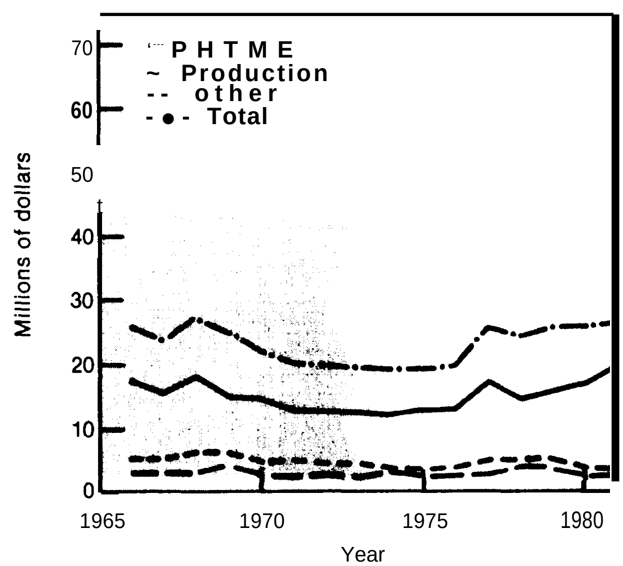
SAES expenditures on production research were the largest component of expenditures from other

Figure 18.—SAES Expenditures From Other Federal Sources on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in current dollars)



SOURCE Off Ice of Technology Assessment

Figure 19.—SAES Expenditures From Other Federal Sources on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in constant dollars)



SOURCE. Office of Technology Assessment

Federal funds during the 1966-81 period. With some minor deviations, these expenditures exhibit patterns in both current and constant dollars that are similar to those exhibited by total agricultural research expenditures. During the 16-year period, expenditures on production research were about two-thirds of the total agricultural research expenditures from other Federal funds. In current dollars, SAES expenditures on production research from other Federal funds increased by 224 percent from 1966 to 1981. In constant dollars, the expenditures on production research increased 11 percent.

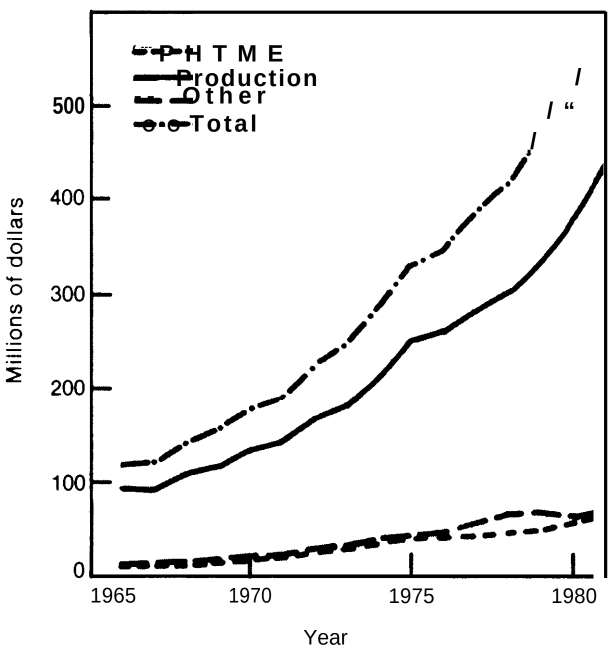
SAES expenditures from other Federal sources on PHTME research show some minor variation during the 1966-81 period, but overall the current dollar expenditures increased by 153 percent from 1966 to 1981. In constant dollars, there was a decrease of 14 percent.

In both current and constant dollars, SAES expenditures from other Federal sources on "other" research increased during the 1966-81 period and peaked in 1980. In current dollars, the overall increase from 1966 to 1981 was 290 percent, and in constant dollars, the increase was 33 percent. Expenditures on "other" agricultural research as a percent of total SAES expenditures on agricultural research from other Federal sources was about 12 percent during the late 1960's and early to mid-1970's, but increased to a high of 18 percent in 1978, and then declined to slightly under 15 percent in 1981.

SAES Expenditures From State Appropriations

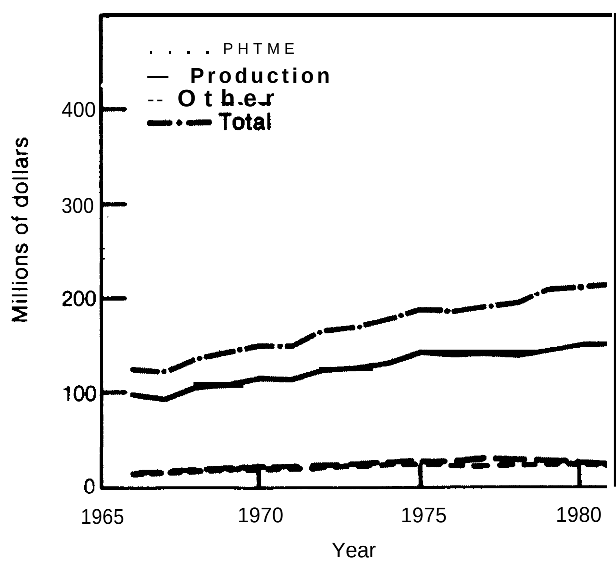
SAES current dollar expenditures on production, PHTME, other, and total agricultural research from State appropriations and sales for the 1966-81 period are presented in figure 20, and constant dollar expenditures are presented in figure 21. SAES current dollar expenditures from State appropriations and sales on total agricultural research increased steadily from $118 million in 1966 to $586 million in 1981, which is an increase of 397 percent. The constant dollar expenditures increased fairly steadily from 1966 to 1981, and the overall increase was 70 percent.

Figure 20.—SAES Expenditures From State Appropriations on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in current dollars)



SOURCE Office of Technology Assessment

Figure 21.—SAES Expenditures From State Appropriations on Production, PHTME, Other, and Total Agricultural Research, 1966-81 (in constant dollars)



SOURCE Office of Technology Assessment.

Expenditures on production research were the largest component of total SAES agricultural research expenditures from State appropriations and sales, and in both current and constant dollars, these expenditures exhibit patterns similar to those for SAES expenditures on all agricultural research. In 1966, expenditures on production research accounted for 78 percent of total SAES agricultural research expenditures from State appropriations and sales, and in 1981, for 75 percent. In current dollars, the expenditures on production research increased by 377 percent from 1966 to 1981. The corresponding increase in constant dollars was 63 percent.

SAES expenditures on PHTME research funded from State appropriations and sales steadily increased in current dollars from $14 million in 1966 to $71 million in 1981. The overall increase from 1966 to 1981 was 404 percent. Constant dollar expenditures on PHTME research increased steadily over the 16-year period, and the overall increase from 1966 to 1981 was 72 percent. Throughout the 16-year period, expenditures on PHTME research were about 12 percent of the total SAES agricultural research expenditures from State appropriations and sales.

State appropriations recently have accounted for the bulk of the total SAES expenditures on PHTME research. In 1966, State appropriations accounted for 43 percent of these funds and those of the Federal Government, 53 percent. These proportions gradually changed over the 16-year period, and by 1981, State appropriations accounted for 56 percent of PHTME research funds and those of the Federal Government, 38 percent. This has significant implications on the issue of equity in funding PHTME research, discussed in the next chapter,

The patterns of SAES expenditures on "other" research funded from State appropriations and sales are similar to the patterns for PHTME expenditures, except from 1977 to 1978 when expenditures on "other" research increased nearly $14 million more than did expenditures on PHTME research. In current dollars, SAES expenditures on other research funded from State appropriations and sales increased 540 percent from 1966 to 1981. The corresponding increase in constant dollars was about 118 percent. Expenditures on other research were 10 percent of total SAES expenditures on agricultural research funded from State appropriations and sales in 1966 and were 13 percent of these expenditures in 1981.

SAES Expenditures From Private Industry Funds

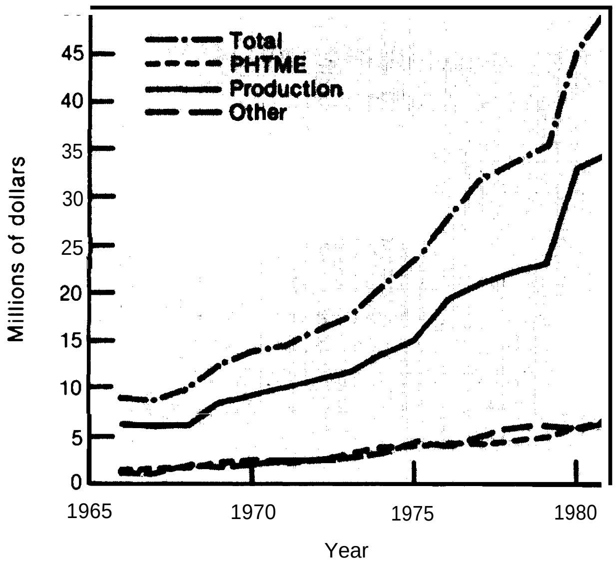
SAES expenditures on production, PHTME, other, and total agricultural research from funds provided by private industry during the 1966-81 period are presented in current dollars in figure 22, and constant dollar expenditures are presented in figure 23. Current dollar expenditures from private industry sources on total agricultural research increased steadily from 1966 to 1981, for an overall percentage increase of 484 percent. The corresponding increase in constant dollars was 99 percent.

Expenditures on production research *were* the largest component of total SAES agricultural research funds from private industry. Expenditures on production research were 72 percent of total research funds from private industry in 1966 and 69 percent in 1981. From 1966 to 1981, SAES expenditures on production research funded by private industry increased by 464 percent. Constant dollar expenditures increased by 54 percent.

SAES expenditures on PHTME research funded by private industry varied during the 1966-81 period, but current dollar expenditures increased 462 percent overall. In constant dollars, the expenditures on PHTME research increased by 92 percent from 1966 to 1981. Although these percentages are fairly high, the dollar amounts spent were quite small—the largest expenditure during the 16-year period was $7.7 million for 1981.

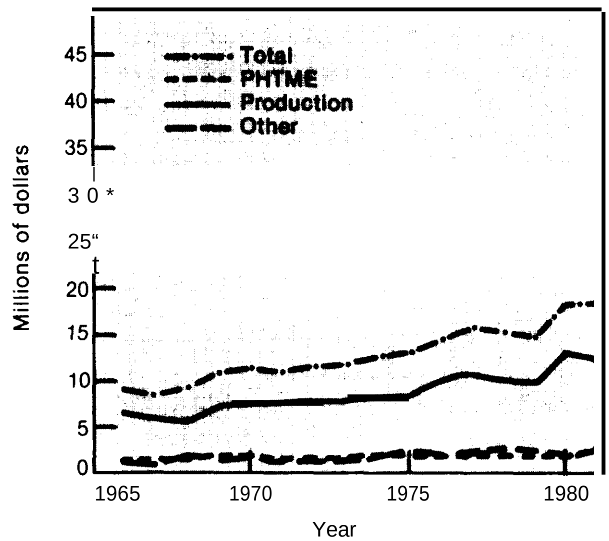
SAES expenditures on "other" research from private industry sources were about the same magnitude as those for PHTME research. From 1966 to 1981, the current dollar expenditures on other research increased 629 percent, while constant dollar expenditures increased by 149 percent. The expenditures on "other" agricultural research were 12 percent of the total SAES agricultural research funds from private industry sources in 1966 and 15 percent in 1981,

Figure 22.—SAES Expenditures From Private Industry Funds on Production, PHTME, Other, and Total Agricultural Research, 1966-81
(in current dollars)



SOURCE: Off Ice of Technology Assessment.

Figure 23.—SAES Expenditures From Private Industry Funds on Production, PHTME, Other, and Total Agricultural Research, 1966-81
(in constant dollars)



SOURCE: Office of Technology Assessment.

PRINCIPAL FINDINGS

- The largest component of USDA research is production research. In 1981, current dollar expenditures on production research totaled $308.2 million or 64 percent of total USDA research, while current dollar expenditures on PHTME research totaled $132.2 million or 18 percent of USDA research expenditures.
- In constant dollars, USDA expenditures for PHTME research declined 17 percent from 1966 to 1981.
- Within USDA, PHTME research is conducted chiefly by two agencies: 1) ARS, and 2) ERS. In constant dollars, ARS expenditures on post-harvest technology research declined by 20 percent from 1966 to 1981. The largest component of ERS research expenditures is marketing economics research. However, ERS expenditures on marketing economics research decreased by 10 percent in constant dollars from 1966 to 1981.
- The largest component of SAES research, like USDA 'research; is production research. In 1981, current dollar expenditures on production research were $656.4 million or 72 percent of SAES research expenditures, while current dollar expenditures on PHTME research were $127.3 million or 14 percent of SAES research expenditures.
- In constant dollars, SAES expenditures for PHTME research increased by 32 percent from 1966 to 1981.
- The majority of funds for PHTME research in SAES now come from State appropriations. From 1966 to 1981, State appropriations increased from 43 to 56 percent of SAES funds for PHTME research, while the Federal funds to SAES for PHTME research decreased from 53 to 38 percent.

CHAPTER 3 REFERENCES

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2. Office of Technology Assessment, An *Assessment of the U.S. Food and Agricultural Research System* (Washington, D. C.: U.S. Congress, December 1981),

Chapter 4

Benefits, Burdens, and Quality of Postharvest Technology and Marketing Economics Research

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Chapter 4

Benefits, Burdens, and Quality of Postharvest Technology and Marketing Economics Research*

The rationale for public funding of postharvest technology and marketing economics (PHTME) research, Federal funding in particular, is that such research yields benefits to society that would not be realized in the absence of public funding, and furthermore, that these societal benefits are well in excess of societal costs. This chapter discusses the nature of the benefits from PHTME research to farmers, marketing firms, consumers, and others.

The benefits of PHTME research to society are yielded over time and, an appropriate timeframe is required to evaluate such benefits. Time lags occur that can slow the benefits from reaching society (7). Such lag periods may include in part:

- the length of the research itself,
- the time between when research results become available and the time when society starts to use them, and
- the time it takes for a major sector of society to use or adapt the research to their needs.

The benefits society receives from increased productivity resulting from PHTME research follows a bell-shaped curve *over* time, one similar to production-oriented agricultural research where increased productivity reaches its maximum during the sixth year (7).

Moreover, many of the benefits of food and agricultural research accrue to parties (e. g., farm producers or consumers) other than the parties funding or conducting the research. Improvements in storage, processing, retailing, and transportations systems, for example, can benefit farm producers by allowing them to sell their products in off seasons or in nonproducing areas of the country. Such improvements similarly can benefit consumers by increasing food availability and lowering food costs if such benefits are passed along. Benefits from activities of a private or public organization for which the organization is not compensated are termed positive externalities or spillovers. The association of positive externalities with PHTME research has significant implications for the funding of such research in both the private and the public sectors.

Because they are generally motivated by profit, private firms have an incentive to invest in those types of PHTME research for which they anticipate reaping a sufficiently large return on their investment. Factors that help a firm capture benefits from its own research include patentability, patent enforceability, and obstacles to the imitation of such research (26). These factors are present, in the area of mechanization research, for example, a research field traditionally conducted by the private sector.

In some cases, however, private firms have little incentive to invest in research because they anticipate being unable to capture a large share of the benefits from their own research. It may be that most of the benefits will accrue to producers, other firms, or consumers. This maybe a problem even with patent enforceability, because of factors such as imperfect consumer knowledge, product emulation, and the prohibitive costs of collecting benefits from research. From a societal perspective the research may be of considerable importance, but if a firm is unable to reap the benefits it will have little incentive to conduct the research. Thus, to help ensure the optimum level of societal investment in such research, public sector support may be needed.

* The material in this section draws heavily on "Nature and Flow of Benefits From Ag-Food Research, " prepared by Fred C. White, B. R. Eddleman, and J. C. Purcell; and "An Evaluation of Methods for Examining the Quality of Agricultural Research," prepared by Robert E. Evenson and Bryan D. Wright in An *Assessment of the United States Food and Agricultural Research System,* Vol. II, Part C (Washington, D. C.: Office of Technology Assessment, U.S. Congress, April 1982).

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However, the problem of spillovers, as discussed further in this chapter, can also arise within the public sector. Benefits resulting from the research of State agricultural experiment stations (SAES), for example, frequently are reaped not only by producers in the State in which the research is conducted but also by producers in other States (25). These benefits similarly maybe reaped not only by consumers in the State where the research is conducted but by consumers in other States, as well. From the standpoint of equity, it may be desirable to provide Federal funding for such research.

Overall, a high degree of uncertainty about the possible outcomes of research increases the likelihood of underinvestment in research relative to the optimum level for society (36). Some food and agricultural research projects undertaken do not turn out to be economically successful. A small firm that is able to pursue only a few projects faces a high probability that none of its projects will be successful. Historically, however, when all successful and unsuccessful projects in food and agricultural research are considered, the average or expected rate of return on investment has been favorable (9). In a large firm or in a large aggregate such as the United States, the productivity of food and agricultural research can be viewed in terms of a framework of risk rather than of pure uncertainty.

The following sections of this chapter examine the benefits, burdens, and quality of PHTME research. Chapter 5 further delineates the roles of public and private research participants.

BENEFITS FROM PHTME RESEARCH

PHTME research is designed to provide products where and when needed, in the form desired, and with maximum economic efficiency. PHTME research can make more food available by improving processing, upgrading products, preventing waste, and providing for use of products previously not considered usable. Such research also can reduce marketing costs by improving efficiency in storage and transportation of food and by improving efficiency of use of resources.

The primary aims of PHTME research are to: 1) increase productivity in the food processing and marketing sectors and reduce the real cost of food; 2) maintain or enhance the nutritional value, quality, and safety of food; 3) develop new or improved food products; and 4) provide information that policymakers and others can use in decisionmaking.

Reduced Food Processing and Marketing Costs

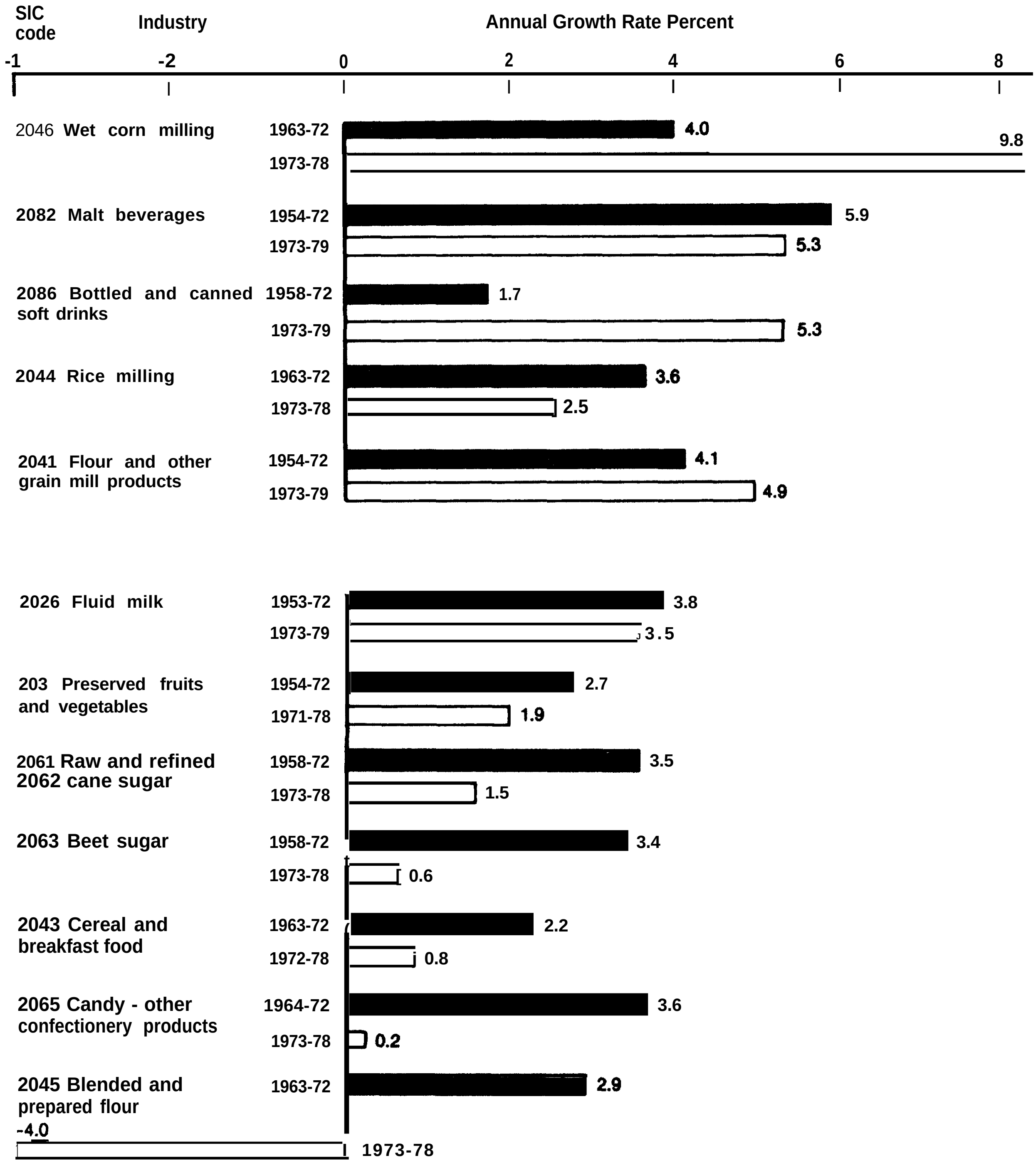
An estimated 70 percent of food costs to consumers is attributable to assembling, processing, transporting, and distributing food; the remaining 30 percent goes to farmers and their suppliers (see also ch. 2). Furthermore, rising marketing costs are the main cause of rising food costs. By leading to increases in labor productivity and other developments, PHTME research can reduce the costs of processing and marketing food, and thus it may lower food costs to consumers.

Reducing Costs Through Increased Labor Productivity

The largest cost component in the food processing and marketing sector by far is direct labor, accounting for 45 percent of total marketing costs, followed by food packaging costs (12 percent) and the costs of shipping food by rail and truck (8 percent). Thus, research that leads to increases in labor productivity offers the greatest potential for constraining increases in consumer food prices (s).

For most industries that process and distribute farm products, the rate of labor productivity growth (output per employee hour) since 1972 has declined in comparison to the rate for previous years (see ch. 2). Figure 24 shows trends in labor productivity growth among processors of farm products. During the period 1973 to 1979, increases in rates of growth of labor productivity in the food processing sector occurred in grain milling and soft drinks; whereas in cereal and

Figure 24.— Estimated Labor Productivity Growth Rates (output per employee hour) in the Food Processing Sector, 1954-72 and 1973-79

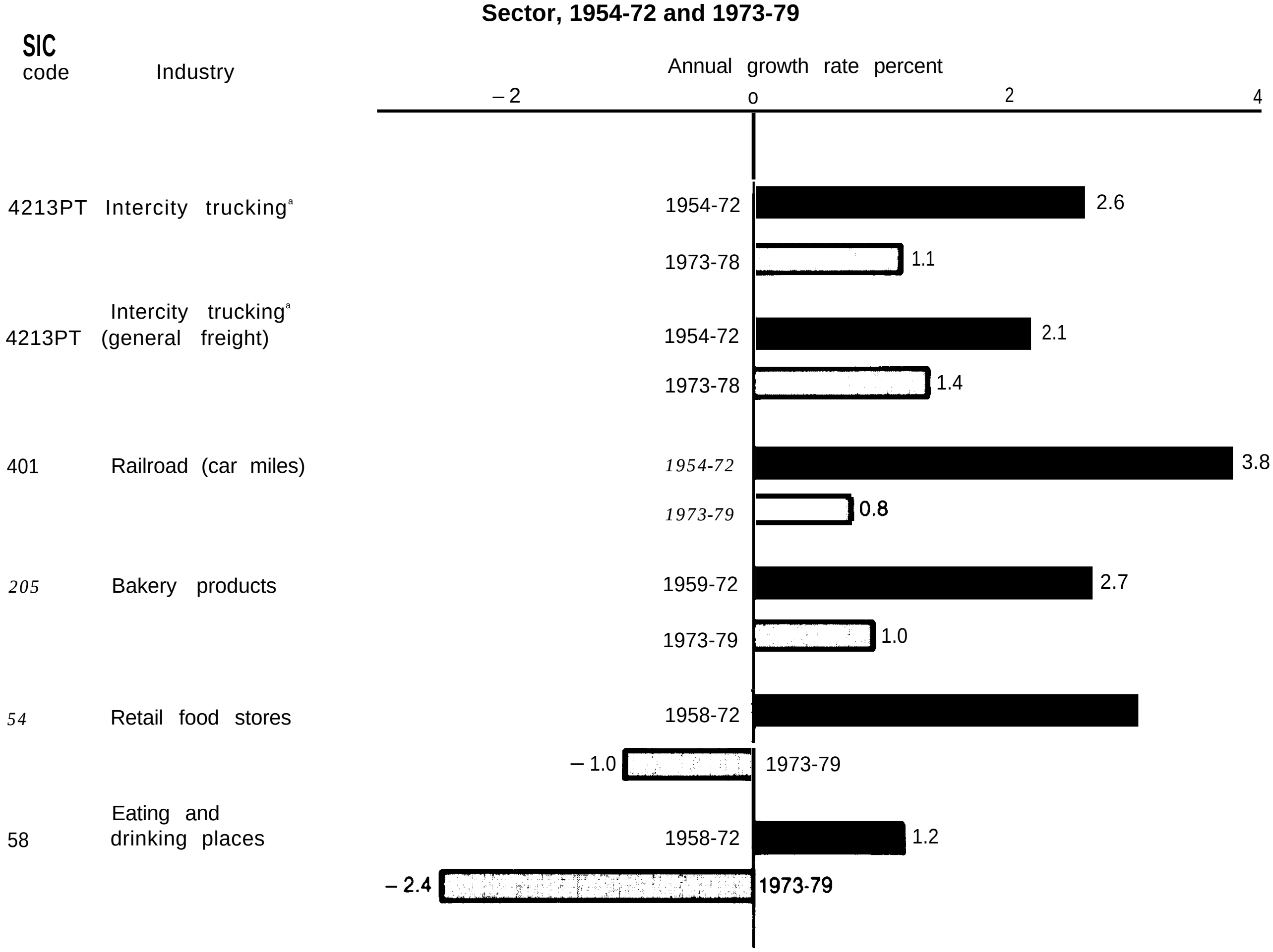


SOURCE Bureau of Labor Statistics, *Productivity Indexes for Selected Industries,* 1979 Edition, Bul. No. 2054, December 1979 [Tiegen, 1981] breakfast foods, beet sugar, and candy manufacturing, labor productivity remained almost constant and the blended flour industry declined at an annual **rate of 4.0 percent. Although the Bureau of Labor Statistics does not report productivity in meatpacking, output per employee hour as computed from the Industrial Production Indexes of the Federal Reserve Board showed no change from 1971 to 1978 (28).**

All labor productivity growth rates in the food distribution sector have declined significantly since 1972 (see fig. 25). In particular, labor productivity in food stores and eating and drinking establishments had a negative growth rate. In food stores, longer shopping hours essentially accounted for the same volume of sales and is considered a major cause of decline; automated checkout systems have not yet affected labor productivity in food retailing. Although fast-food chains have made organizational and technological improvements, increases in hours worked and the number of small, marginal enterprises have held productivity down (4).

Lagging labor productivity growth rates in the food processing and distributing sectors have contributed significantly to increased rates of food price inflation (see ch. 2). In the period 1960 to 1965, the annual rate of increase in food prices

Figure 25.— Estimated Labor Productivity Growth Rates (output per employee hour) in the Food Distribution Sector, 1954-72 and 1973-79



[a]Output per employee.

SOURCE: Bureau of Labor Statistics, Productivity *Indexes for Selected Industries, 1979 Edition,* Bulletin No. 2054, December 1979 (Teigen, 1981).

was 1.1 percent; in the period 1966 to 1972, the annual rate of increase in food prices rose to 3.9 percent, and in 1973, it reached 7.7 percent. Although annual wage gains during the period 1950 to 1965 (3.9 percent) and 1966 to 1972 (7.5 percent) outpaced the annual food price gains, they barely kept pace during the period 1973 to 1979 (7.5 percent). The real price of food in the period 1973 to 1980, in terms of hourly earnings, was not significantly different from 1967 level (see fig. 26).

Reducing Costs Through Improvements in Processing and Preservation

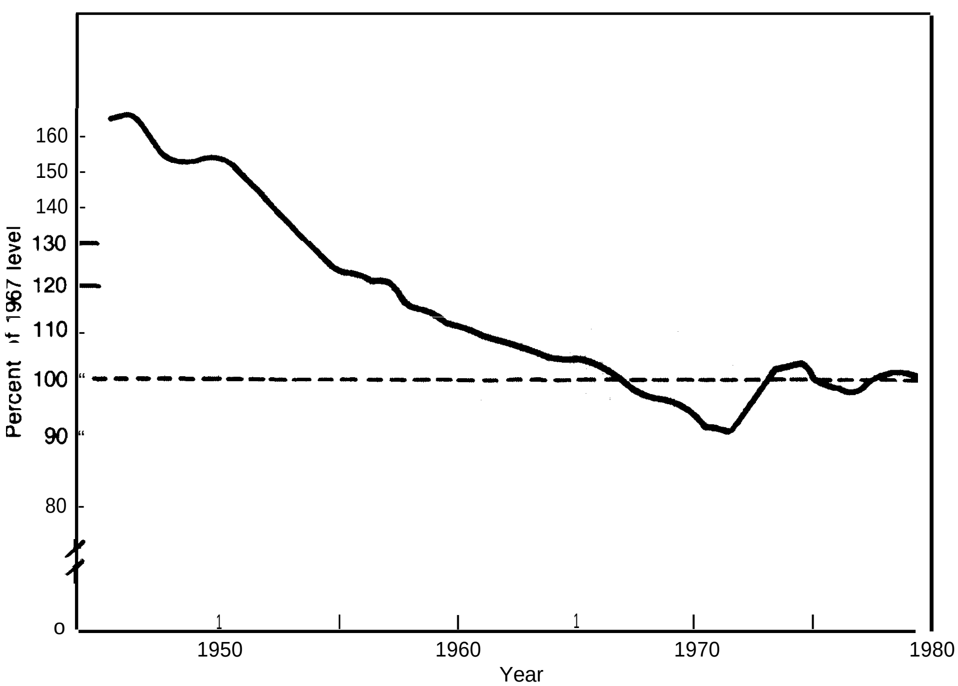
Many food products are wasted because of improper methods of processing and preservation. In some cases, a particular treatment can make food products available that would otherwise be wasted. Research to develop treatments that would be economically feasible to use is currently being conducted (33). Reducing food losses due to wastes could result in cost savings to consumers. In the area of preservation, the product's safety and other factors must be taken into consideration. In addition, the food must be acceptable to consumers.

Both better use of food materials through improvements in processing and preservation, and research that reduces energy and water use for processing may lower food costs. Given the present level of resource use, such cost savings could be substantial. For example, drying processes are energy-intensive and could be made more efficient. Fabricated foods can lower food costs by substituting cheaper grain ingredients for more expensive livestock ingredients. Improved knowledge of physical and chemical properties of food may result in savings related to food storage, processing, and handling.

Reducing Costs Through Efficient Marketing and Distribution

In the last 30 years, changes in the marketing and distribution of food have been significant, as

Figure 26.—Real Price of Food[a], 1947-80



[a]Consumer price index for food relative to private nonagricultural hourly earnings, adjusted for overtime and interindustry shifts

SOURCE. Lloyd D Teigen, "Productivity A Food and Agriculture Perspective, " mimeo draft, U.S. Department of Agriculture, Economic Research Service, August 1981 evidenced by the expansion of supermarkets. Supermarkets have reduced the retail cost of food to consumers by some 15 to 25 percent (15). These cost reductions were achieved through labor reductions made possible through self-service and large-volume operations in transportation, storage, and distribution.

Thus, research designed to improve efficiency in food marketing and distribution can be used to lower marketing costs. Improved coordination of marketing activities, in the private and public sectors, is needed to move food more efficiently through marketing and distribution channels.

Enhanced Quality, Nutritional Value, and Safety of Food

The quality of food products primarily refers to such products' esthetic characteristics, but may also refer to their nutrient value, whether naturally occurring or introduced by processing and preservation technology. Operations relating to storage, handling, shipping, intermediate processing, packaging, delivery to merchants, shelf life, and final sale of food products can materially influence such products' quality, nutritional value, and safety.

Some nutrients, notably vitamins and fats but proteins and carbohydrates as well, are sensitive to pH, oxygen, heat, and light, and are particularly susceptible to damage in the presence of certain trace elements. PHTME research can help minimize or negate the influence of these factors and the effects of environmental conditions on development of mycotoxins (naturally occurring toxic contaminants in food produced by molds) and the effects of insect and rodent infestation on nutrient content and safety.

Fortification and enrichment of foods are means to improve nutritional value of food. Fortification and enrichment of foods generally increase the food's retail cost, and this increase must be weighed against benefits derived from the practice. Actions that have helped improve U.S. diets include the addition of vitamins B_1, B_2, and niacin to cereal products, vitamin D to milk, iodine to salt, and fluoride to drinking water, Iron fortification of foods is another example, although some controversy exists regarding the benefits of this practice.

Consumers almost exclusively benefit from research that: 1) increases the supply of nutrients; 2) determines the nutritional requirements and food consumption practices of various consumer groups; 3) increases the nutritional value of foods; and 4) reduces the potential hazards of naturally occurring toxins, food preservatives, or other additives used in processing, insect and rodent contamination, residual pesticides used in production, and other inadvertent contaminants. Producers may benefit from, be unaffected by, or be disadvantaged by such research (36).

In some cases, food products may contribute to nutritional problems. Examples of such products are the high-calorie, low-nutrient snack foods and food substitutes that are of lower nutritional value than the foods they replace. There is a need to consider nutritional value as an integral part of food quality, since an increasing proportion of the food supply is modified by postharvest processing.

New or Improved Food Products

PHTME research can contribute to development of new or improved food products that directly benefit consumers. Such developments include food products which substitute vegetable for animal protein and use of other alternative food sources.

The importance of plant protein in the diets of people in industrialized countries such as the United States is expected to increase, relative to the demand for meat, fish, and egg protein. Plant protein products can be introduced into the diet either as food ingredients (e.g., textured soy flour as an extender added to ground beef) or as ersatz foods (e.g., simulated chicken or ham). Food blends have been developed through research from a variety of cereals and oilseeds, Lipid protein concentrate derived from soybeans can be used as a beverage base. Raw soybeans can be used to produce soy flours, protein concentrates, soybean isolates, or textured products.

Other possible alternative food sources include: 1) fats and oils from controlled animal feeding and breeding, controlled fish farming, single-cell cultivation (yeast/fungi), selective plant propagation, and synthesis from petroleum and enzymic processes; 2) meat or simulated meat products from new animal species and vegetable and microbial sources; and 3) carbohydrates such as glucose syrups from cellulose, chemically synthesized sugar, or low energy substitutes replacing starch (13). Research on new or improved food products may have the greatest potential for providing food nutrients to the world population at minimum or reasonable food costs (36).

Reduction of Food Losses Due to Waste

The National Academy of Sciences has estimated that research on reducing food losses due to pests could save $1.5 billion annually in the United States (19). Research on reducing the storage and transportation losses of fruits and vegetables, it estimated, could increase the supply of these products from 15 to 30 percent (19). The benefits from basic research in areas such as establishing physiological and biological interactions and analyzing metabolic processes of micro-organisms, although more difficult to quantify, would very likely include the prevention of food losses and improved food quality.

As discussed earlier, many food products are wasted because of improper methods of processing and preservation. Particular treatments can make food products available that would otherwise be wasted. Research to develop treatments that would be economically feasible to use is currently being conducted (33), Reducing such food losses could result in cost savings to consumers.

Information for Decisionmaking

PHTME research can provide information on markets, prices, and government regulations that farmers, processors, distributors, consumers, and policy makers can use in making decisions. Research on industry competitiveness can provide information to producer groups and the public on the forces that are shaping this industry, information to assist producers in long-range planning, and information to policy makers on alternative legislative proposals in relation to the projected change in the industry.

PHTME research that provides information about current and future market conditions, including future supply and demand, for example, can be useful to individual firms. This is the case in the area of grain marketing. Food and industrial uses of grain and grain products are increasing rapidly, and the composition of products produced by U.S. grain processors has changed, reflecting shifts in consumer preferences. In order for individual firms in the grain marketing industry to make effective and efficient adjustments, they may need information about how changes in economic and institutional factors affect the demand for grain and grain products *(33).*

PHTME research that assesses the impact of government regulations can provide valuable information for policymakers. Regulations intended to improve industry performance, for example, in the red meat industry, may sometimes have unintentional and costly side effects, and the benefits derived from the regulations may sometimes be eroded. This situation leads to numerous inefficiencies that affect the ability of firms to compete, adopt new technologies, and experience growth in output and sales. Research that assesses the impact of regulations provides policymakers with the necessary information to assess the benefits and costs of the regulations.

PHTME research that measures the competitive relationships among firms producing a similar set of products considers both how the organization of the industry affects its behavior and performance and what determines how an industry is organized and how it changes. Important aspects of this research include the degree of market concentration, barriers to entry, the types of competing organizations, and regulations that affect competitive behavior. Such research can be useful to industry, consumers, and policy makers.

Recent studies indicate that increasing concentration in the food processing and retailing subsectors may increase real food prices to consumers. Parker and Conner (24) found that the following monopolistic trends in the food manufacturing subsector, which were identified by the National Commission on Food Marketing in 1966, have continued: 1) a decline in company numbers; 2) an increase in concentration; 3) a substantial increase in the conglomerate nature of leading food manufacturing firms; 4) an increase in the number of large acquisitions by the larger companies; 5) substantial increases in product differentiation expenditures by large food manufacturers; and 6) a growing differential between profitability of large versus medium and small food manufacturers. The consumer loss attributable to these monopolistic characteristics was estimated to be approximately *$12* billion to $14 billion annually, or as much as 25 percent of the value added to food products by food manufacturers (24). *

*This conclusion was rebutted by O'Rourke and Greig (23) and Bullock (l).

Net profits and food prices of large food chains were positively and significantly related to market concentration and a chain's relative market share (17).** Marion's findings tend to refute the notion that higher profits for dominant firms in concentrated markets are due to such firms' efficiency and lower costs. Increased profits by firms in noncompetitively structured markets account for about one-third of the increases in food prices *(17).* Thus, policy-oriented PHTME research directed toward improving competition in the food processing and retailing subsectors potentially could result in substantial benefits (i.e., lower costs) to consumers and farm producers.

** This study used cross-sectional data, not time series data. Thus, efficiency and costs could not be accounted for over time.

BENEFICIARIES OF PHTME RESEARCH

Analysis of the flow of benefits from food and agricultural research— including PHTME research —focuses primarily on the distribution of benefits between domestic consumers and producers. The analytical framework is the concept of economic surplus and the partitioning of this surplus into the portion accruing to buyers (i.e., consumer surplus) and the portion accruing to sellers (i.e., producer surplus) (2,38).

Farm Producers

In the United States, the demand for food is only slightly responsive to changes in the price of food and rising personal income has almost no effect on per capita food consumption. Thus, the domestic demand for food increases at about the same rate as the population growth. In this situation, technology that increases output in excess of that needed to meet demand growth results in depressed prices.

The food processing and marketing system enhances the value of farm commodities by changing their form and distributing the products over time and space. For example, few households buy wheat, but some buy flour and most buy bread. The demand for wheat is largely derived from the demand for flour, and the demand for flour is largely derived from the demand for bread.

PHTME research may lead to an improvement in the food processing sector which reduces costs to that sector; the reduction in costs to the food processing sector may or may not be passed on to consumers. An improvement, for example, in transportation or distribution technology in the food marketing sector might reduce costs to farmers and could increase their income.

Consumers and General Economy

Benefits to consumers from PHTME research may include increased availability of food and reduced retail food costs. A technological change that reduces the costs of marketing services may reduce the retail price to consumers. The farm price could be expected to increase, but the retail price would be expected to decline with reduced marketing margins. *

Consumers (and farmers, too) also may benefit from research to improve market or price infor-

'These relationships hold for a competitive market structure in which changes in margins are reflected throughout the marketing system. Both the derived supply at retail, which is dependent on farm supply and the marketing margin, and the derived demand at the farm level, which is dependent on the retail demand and the marketing margin, would shift in a competitive market as a result of a reduction in marketing costs. The impacts on consumers of a technological change in the marketing sector are dependent on the price elasticities of supply and demand and the magnitude of cost savings resultin8 from the technological change.

mation. If producers incorrectly estimate the price of a commodity above the market equilibrium price, they will produce a quantity larger than the market equilibrium quantity. The resulting price, however, will be lower than producers expected and result in a net loss to society. If marketing economics research such as econometric modeling lead to a price forecast close to the market equilibrium, this net social loss will be minimized (22).

Consumers also may benefit from improved quality, nutrition, safety, and convenience of foods. Some of these benefits seem to be concentrated among certain groups of families. It is estimated that the diets of *20* percent of the households in the United States provide less than two-thirds of the recommended daily allowance of one or more nutrients (15), Malnutrition is more evident among low-income families, and relationships between diet and chronic illnesses have been identified (30). PHTME research that improves the quality and safety of food products is likely to affect consumers in all income categories beneficially.

From the standpoint of equity, the distributional impacts of agricultural research—including PHTME research-are important. In the analysis that follows, the distribution of benefits from agricultural research is estimated on the basis of consumer food expenditures. Each dollar of food expenditure is assumed to be related to the same amount of research benefits, whether the expenditure is made by high- or low-income families.

The relationship between family income and agricultural research benefits for average size families in six family income categories are given in table 8. Family income ranges from under $5,000 in the lowest class to over $20,000 in the highest; average family size ranges from 2.93 persons in the lowest income class to *3.79 in* the highest. The present value of average benefits per family for the various income classes shown in table *8* may be interpreted as the benefits accruing to each family as a result of agricultural research expenditures in that year. * Average benefits per family, which increase with the level of family income, range from $16.20 in the lowest income category to $30.74 in the highest.

The ratio of benefits to family income is almost four times higher for the lowest income class than for the highest, indicating that food and agricultural research has a greater beneficial impact on low-income families than on high-income families in relation to family income. For some commodities, the distribution of consumer benefits from research tends to be biased in favor of families

● Even though benefits would be realized through time, this stream of benefits was discounted with a 10-percent discount rate to find the present value of benefits (8).

Table 8.— Relationship Between Food and Agricultural Research Benefits and Family Income

Family income class	Distribution of population[a]	Average size family[b]	Average family income	Average benefits per family[c] (present value)
Under $5,000	18.190/o	2.93	$3,981	$16.20
$5,000 -$8,000	14.14	3.15	7,922	19.06
$8,000-$ 12,000	21.17	3.28	10,528	20.13
$12,000-$ 15,000	14.47	3.48	13,458	22.63
$15,000-$20,000	16.07	3.68	17,371	25.91
Over $20,000	15.96	3.79	28,953	30.74

[a]Anthony E. Gallo and William T. Boehm, "Food Expenditures by Income Group," National Food Review, NFT-3, USDA, ESCS, Washington, D. C., June 1978.
[b]U.S. Department of Commerce, Bureau of the Census, Current Population **Reports, Series** P-60, **No.** 101, "Money Income in 1974 of Families and Persons in the U. S." (Washington, D.C.: U.S. Government Printing Office, 1976).
[c]Total consumer benefits are calculated according **to** the equation:

$$TB_C = ½ \times MVP_R \times RE \times D$$

where TB_C is total consumer benefits from ag-food research; MVP_R is marginal value product of research (Davis); RE is production oriented research expenditures in 1974 (Budget of the US Government; USDA, *Inventory of* Agricultural Research, U.S. Department of the Treasury); and D is the discount factor over 13 years at 10 percent (Lu, Cline, and Quance) Total consumer benefits are allocated to income classes according to the level of food expenditures.

SOURCE: Fred C. White, B. R., Eddleman, and J. C Purcell, "Nature and Flow of Benefits From Agriculture-Food Research," in An *Assessment of the United States Food and Agricultural Research System,* Vol. 11, Part C (Washington, D.C. Office of Technology Assessment, U.S. Congress, April 1982).

with higher income. The larger the quantity consumed in the higher income categories relative to the lower income categories (e.g., pork, poultry, beef, and dairy products), the more favorable the distribution of benefits to higher income families.

Marketing Firms

Competition among marketing firms results in lower costs of marketing services being passed on to consumers and producers. As indicated earlier in this chapter, however, there is evidence that the food marketing system does not conform to a competitive market, particularly at the regional and local market level (17,24).

Marketing firms with some monopolistic power may retain a part of the cost savings from technological change in the form of increased profits (10). Monopolies, because of profits captured and desire to retain monopolistic control, maybe willing to invest in private research.

The more competitive the industry, the less incentive there is for private research, because the benefits accrue to consumers and farmers. In a less competitive industry, however, private research is more profitable for the individual firm, and private research may reduce the level of competition.

Public research may enhance competition or reduce market power in a particular subsector. The benefits from public food and agricultural research in a highly competitive marketing sector accrue to consumers and to farmers.

Labor and Other Input Suppliers

Technology that changes the relative productivity of resources shifts the distribution of income among resources (12). These changes have reduced the proportion of total food and agricultural income attributed to labor and increased the proportion attributed to capital.

Changes in the proportion of income attributable to labor depends on the type of technology. Labor-saving technology reduces the demand for labor. Mechanical technology that has been developed almost entirely by the private sector generally can be characterized as labor-saving *(6).*

Research that develops more productive postharvest technologies usually makes possible increased labor productivity and provides opportunity for increasing wages and salaries without necessarily placing an upward pressure on retail prices. The process may displace part of the labor force thus requiring them to find other employment.

Research that provides for more efficient use of energy and capital provides more residual capital for increased wages and salaries in real terms. Conversely, rising prices of energy and investment funds (through rising interest rates) place downward pressures on salaries and wages, upward pressures on retail prices, and downward pressures on farm prices. These are the conditions that dominated during most of the past decade. Such pressures as rising energy costs can be mitigated by improved efficiencies from PHTME research. Increases in wages and salaries, without compensating increases in labor efficiency, result directly in inflation.

FUNDING AND FLOW OF BENEFITS FROM PHTME RESEARCH

From the standpoint of equity, an important consideration is the extent to which the flow of benefits from PHTME research is related to the sources of funding for such research. Ideally, the beneficiaries of research should pay the research costs. As discussed further below, however, the beneficiaries of PHTME research sometimes do not pay the research costs.

Private Sector Funding Related to Flow of Benefits

Who captures the benefits from public sector and private sector food and agricultural research is a prominent issue in PHTME research. The question is whether a particular research problem area should be addressed through public research if the gains from the research are embodied in private firms' products. In general, there are spillovers or indirect benefits both from public research to the private sector and from the private sector research to society.

If benefits from the results of private sector PHTME research can be captured by the private sector, then there is an incentive for private firms to invest in research activities. Research activities can be distinguished in terms of patentability and patent enforceability of the product, technique, or process that results from the research; the economic life of the technique or process; the technological versus pecuniary effects of the technique or process; and the ability of rival companies to initiate the research and development process (36). These characteristics determine whether net benefits of the research activities can be captured by the private sector.

To the extent that the benefits of research can be captured by firms in the private sector, public sector involvement in the types of research activities from which such benefits flow would be a form of subsidy to private firms. In some cases, however, private sector research activities yield spillover effects and indirect benefits to society. Although no specific case studies have been done for agricultural input or food-processing industries, studies by Mansfield, et al. *(16),* Terleckyj (29), and Griliches (11) of the distribution of gains from private research activities in manufacturing and nonmanufacturing industries indicate that the spillover effects are at least as large as the direct benefits going to firms conducting the research. Thus, the social returns from industry research *are roughly* double the private investment returns. In this regard, substantial social benefits are derived from private industry investments in research activities.

State Government Funding Related to Flow of Benefits

Food and agricultural research financed by one State may benefit the residents of other States. For example, a more energy-efficient food processing technology developed in one State may be adopted in neighboring States to increase efficiency at the same or higher total output.

State boundaries do not coincide with homogenous agricultural regions. PHTME research projects in one State that are addressed to specific local problems likely will produce results applicable to other States. Applied research focused on a specific local problem may be adapted for more general purposes to help meet the needs in other regions. Furthermore, knowledge gained from basic research is disseminated without regard to geographic boundaries.

Spillover benefits generated by State A which accrue to the residents of State B generally are not accounted for by State A policymakers. The argument concerning neglect of these externalities has been that State A will provide **a** smaller level of research expenditures than would be the efficient from society's perspective. Given the possibility of negotiation between States, State B may find it advantageous to pay A to increase its level of research activities. Such a subsidy will reduce A's research costs and lead to a higher level of research activities. The negotiation process likely will be complicated by the fact that spillovers flow in both directions between the two States. Furthermore, the outcome will depend on the relative bargaining strength of the two States and will not necessarily lead to an efficient solution to the benefit problem (18).

If only a few States have an interest in a particular commodity or segment of the marketing system, one of the States might conduct the research, with the research effort being supported by the other States. However, attempting to coordinate these activities involves decisionmaking costs that include the value of time, effort, and direct outlays related to the bargaining process. For those cases in which external benefits from agricultural research affect a large number of decisionmaking units, total decisionmaking costs of effective coordinated action are likely to be large. When the impact on consumers is considered, a large number of States would be concerned with almost all aspects of food and agricultural research.

Federal Government Funding Related to Flow of Benefits

Public goods with significant externalities may be classified as either national or quasi-national public goods. A national public good that is consumed equally by all residents (e. g., national defense) may be provided more efficiently by the Federal Government than by State or local governments. Quasi-national public goods, on the other hand, are consumed on a less comprehensive basis throughout the Nation.

Agricultural research, and especially PHTME research, serves as an excellent example of a quasi-national public good. Financing this research at the State level produces benefits that are consumed by the State's residents, but also provides benefits that pass to other States and nations in the form of externalities. While financing can be produced at either the Federal or State level of government, the presence of externalities indicates a need for the coordination of research among various States.

Partial funding by the Federal Government affords one solution to attaining the nationally desired level of research expenditures. An often-used technique to increase State expenditures for government services is the matching grant, in which the recipient State government is required to match Federal funds with funds from its own sources according to some specified formula. While some Federal grants to States for food and agricultural research (including PHTME research) require matching funds, most States invest more in food and agricultural research than just the amount required to match Federal grants, as shown in chapter 3.

The formula for matching funding should be based on the relative importance of external and internal benefits. Properly designed Federal grant programs direct State expenditures toward levels considered optimal from society's perspective (rather than from the State's perspective) by financing the cost of the external benefits.

An appropriate matching grant program requires identifying and quantifying State benefits and spillovers from agricultural research expenditures. An estimated 55 percent of the change in productivity attributed to technology-oriented research conducted by a State is realized within the State conducting the research, whereas the remaining 45 percent is realized in other States (9). Table 9 shows the estimated spillover benefits from food and agricultural research conducted from 1949 to 1972 in 10 different regions of the country (37). The ratio of external benefits (i. e., spillovers to other regions) to internal benefits (i.e., benefits realized within the region in which the research was conducted) range from a low of 1.31 to 1 in the Northeast region to a high of 2.80 to 1 in the Southern Plains region. The aggregate ratio for all regions is 1.73 to 1.

Table 9 also shows the ratio of Federal to State expenditures for production-oriented food and agricultural research in each of the 10 regions and for all regions combined. By comparing these ratios to the spillover ratios, one can determine whether the Federal Government actually financed the spillovers. The aggregate ratio of Federal to State expenditures is only 1.38, compared to aggregate spillover ratio of 1.73.

Table 9.—Distribution of Benefits From and Funding for Production-Oriented Agricuiturai Research and Extension

Region	Ratio of spillovers to regional benefits[a]	Ratio of Federal to State expenditures[b] 1949-72
Northeast	1.31	0.97
Lake States	2.73	1.10
Corn Belt	2.04	1.25
Northern Plains	1.40	1.63
Appalachian	1.19	1.60
Southeast	1.40	1.37
Delta	2.48	1.80
Southern Plains	2.80	2.10
Mountain	1.60	2.35
Pacific	1.89	0.90
All regions	1.73	1.38

[a]The values measure the benefits accruing to farmers outside the region relative to the benefits accruing to farmers within the region.

[b]Federal expenditures are not limited to these funds going to the State agricultural experiment stations and cooperative extension services under formula and grant programs; they also include Federal funding of under formula and grant programs; they also include Federal funding of production-oriented agricultural research and extension in each region through USDA/ARS, USDA/ERS, and USDA/SCS, The values measure the level of Federal funding from all these sources relative to State funding for agricultural research and extension in each region during 1949 to 1972. The 1949.72 period was used for estimating the relationship between productivity growth and agricultural research/extension investments, based on a 13-year distributive lag estimation technique.

SOURCE: Fred C. White and Joseph Havlicek, Jr., "lnterregional Spillover of Agricultural Research Results and Intergovernmental Finance: Some Preliminary Results," in Evaluation *of Agricultural Research,* Minnesota Agricultural Experiment Station Miscellaneous Publication No, 8, 1981

This analysis suggests that the the Federal Government did not finance the spillover benefits to the Nation as a whole of production-oriented agricultural research conducted in the various regions. In order to align aggregate Federal expenditures with national benefits from production-oriented agricultural research conducted in the various regions, Federal expenditures would have to be increased about 25 percent, Several regions would require a greater percentage increase to yield an equitable distribution among regions.

It could be inferred that a similar analysis for PHTME research might result in the same conclusion. The benefits of PHTME research accrue to regions and to the Nation, not to local areas as is characteristic of production-oriented research, so the ratio of spillovers to regional benefits from PHTME research would likely be at least the production-oriented research ratio of 1.73 or higher. As discussed earlier in chapter 3, almost 50 percent of the PHTME research is conducted by the States, and over 50 percent of SAES funds are from State appropriations for this research. Thus, the ratio of Federal expenditures to State expenditures for PHTME research would likely beat least as low as the 1.38 ratio discussed above, if not lower. Thus, assuming these estimates are realistic, the Federal Government's contribution to PHTME research would have to be increased at least 25 percent to align funding with national benefits.

The benefits from increased productivity of food and agricultural research are divided between producers and consumers. When demand is inelastic and growing slowly, as in the United States during most of the past 50 years, a large share of the gains from innovation are passed on to consumers in the form of lower real food prices. When consumer benefits are combined with producer benefits, the magnitude of spillovers to regional benefits is affected dramatically, as shown in table 10.

Table 10 shows the discounted total net benefits that **accrue** to consumers plus producers per dollar of production-oriented agricultural research and extension (R&E) investment: the internal benefits are presented in the first column of the table, and the spillover benefits are presented in the second column. The third column of table 10 shows the ratio of external benefits to benefits accruing within the region, i.e., the spillover ratio per dollar of R&E investment, and the final column of table 10 shows the actual ratio of Federal expenditures to State expenditures for the production-oriented agricultural R&E within each region (repeated from table 9).

Table 10.—Distribution of Benefits From Production-Oriented Agricultural Research and Extension Investment in Regions of the United States, 1976=88

Region	Total producer and consumer benefits per $1 R&E investment: Inside the region	Total producer and consumer benefits per $1 R&E investment: Outside the region	Ratio of spillovers to regional benefits	Actual ratio of Federal to State R&E expenditures[b] 1949-72
Northeast	$28.39	$13.14	0.46	0.97
Lake States	7.93	36.82	4.64	1.10
Corn Belt	5.19	37.95	7,32	1.25
Northern Plains.	1.20	47.96	40,10	1.63
Appalachian	8.19	34.01	4.15	1.60
Southeast.	7.98	34.45	4.32	1.37
Delta States.	3.38	39.38	11.65	1.80
Southern Plains	8.05	37.99	4,72	2.10
Mountain	2.72	40.35	14.85	2.35
Pacific ... , ...	7.88	34.76	4,41	0.90
All regions	8.62	34.84	4.04	1.38

[a]Discounted at 10 percent.
[b]Includes Federal funding of production-oriented agricultural research and extension in each region through CSRS, ARS, ERS, SCS, and Cooperative Extension relative to State expenditures within the region,

SOURCE' Rod. F. Zimmer, F. C. White, and P. L. Cline, "Regional Welfare and Agricultural Research and Extension in the U.S.," *Agricultural Administration, vol. 9, 1982.*

In all regions except the Northeast, the benefits accruing to residents outside the region conducting the production-oriented agricultural R&E are at least four times larger than the benefits accruing to the residents within the region. The regions with the highest ratios of spillovers to regional benefits are the Northern Plains (40.10), Mountain (14.85), Delta States (11.65), and Corn Belt (7.32). Three of these regions (Northern Plains, Mountain, and Delta States) have relatively fewer consumers than most others; thus, a major proportion of net benefits accrue to consumers in other regions through interstate flows of food products and lower consumer prices in the recipient regions. The Lake States *(4.64),* Appalachian (4.15), Southeast *(4.32),* Southern Plains (4.72), and Pacific (4.41) regions have spillover ratios near the national average for all regions (4.04).

From an equity perspective, the spillover ratios indicate that the Federal Government's share of investment should be more in the Northern Plains, Mountain, Delta States, and Corn Belt regions (e.g., farm producing regions) than in other regions of the Nation that have spillover ratios near the national average. A comparison of the ratio of actual Federal expenditures to State expenditures in each region to the ratio of spillovers to internal benefits in each region indicates that in every region except the Northeast, the spillover ratio is more than double the ratio of Federal expenditures to State expenditures.

Figure 27 shows the regional distribution of benefits resulting from an increase in agricultural R&E expenditures. Distribution of consumer benefits is highly correlated in a positive manner with food purchasing patterns and population density. The Northeast receives *38* percent of all benefits resulting from agricultural R&E investments made throughout the Nation. Other major beneficiaries are the Corn Belt, Pacific, Appalachian, and Southeast regions. Each of these regions receives more than 10 percent of the total benefits.

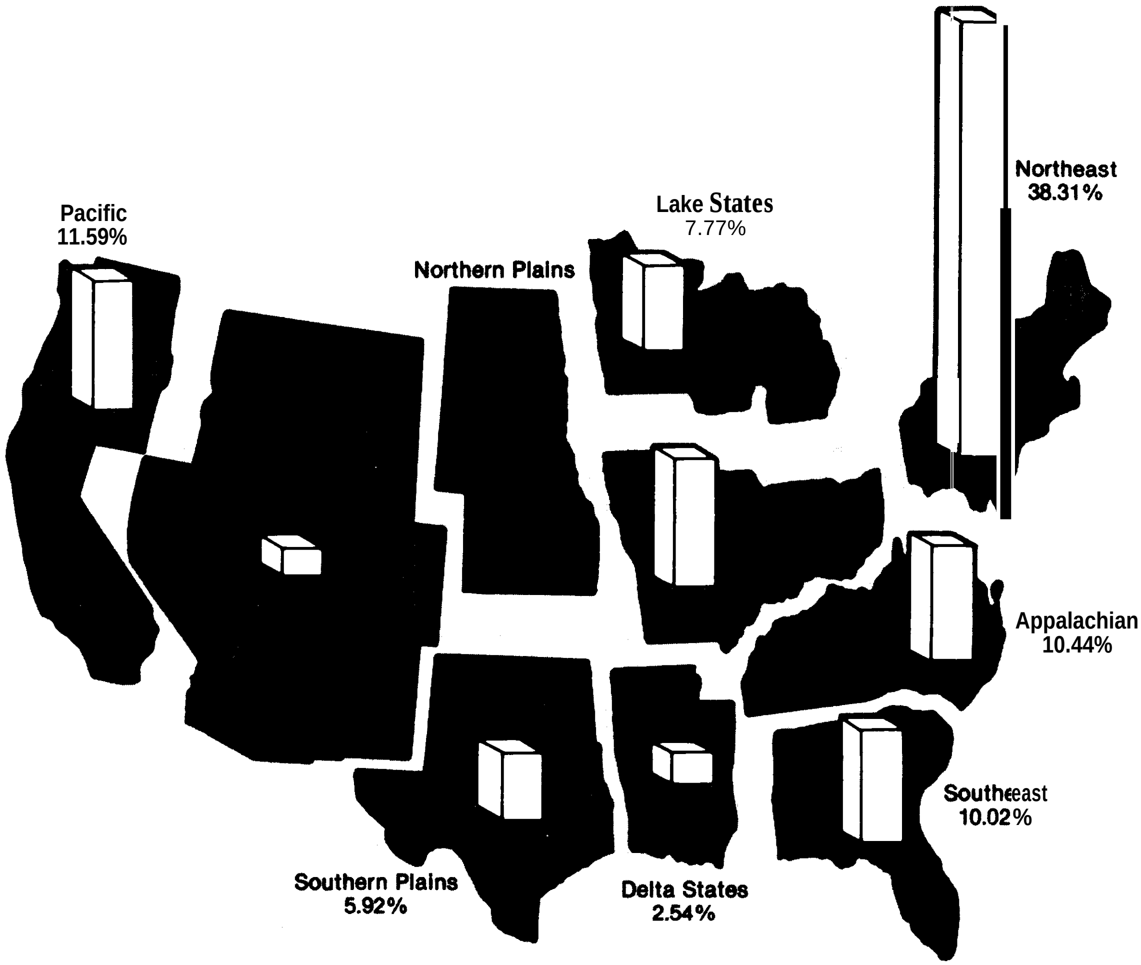
Even though specific data for PHTME research is not available, it could again be inferred with confidence that a similar analysis would result in the same conclusion given the above rationale. For example, the development of a food processing technology which lengthens the shelf life of a food product or the development of a computerized food warehousing system which is based on research conducted in Iowa is just as applicable if used in New York, California, or Texas. Thus, because of the high transferability of the PHTME technology the benefits of PHTME research are highly correlated with food purchasing patterns and population distribution and could result in the same, if not greater, distribution of benefits as above. However, the benefits to consumers in all these major recipient regions are partitioned into such small amounts that the individual consumer cannot feel the connection with increased farm and PHTME productivity realized as a consequence of R&E. Thus, agricultural R&E remain undervalued by consumers as well as by farmers *(3,9,39)*

From an equity perspective, the spillover ratios indicate that the Federal Government's share of research investment should be larger. When such public benefits have an impact on residents of the Nation, funding for the research can be more equitably provided by the Federal Government. The bulk of research investments is financed by States in the major farm producing regions. However, the majority of food consumers—especially those who benefit from PHTME research—live outside these major agricultural States. Thus, taxpayers in major agricultural States are subsidizing PHTME research for consumers in less intensive agricultural States.

BURDENS OF PHTME RESEARCH

Achievements from PHTME research have contributed to the economic stature of the United States, but these achievements have not been attained without certain costs and burdens to society. For that reason, the benefits accruing from such research must be weighed not only against

Figure 27.— Regional Distribution of Benefits Resulting From an Increase in Agricultural Research and Extension Expenditures



SOURCE: Rod F. Zimmer, F C White, and P. L. Cline, "Regional Welfare and Agricultural Research and Extension in the U.S., " *Agricultural Administration,* vol. 9, 1982

the magnitude of whatever dollar and scientific manpower investments are required, but against these other costs and burdens.

Environmental Contamination of Food*

Historically, chemicals such as salt, sugar, and wood smoke have been used to preserve foods. Modern food technology relies extensively on the use of chemicals not only for preservation but also to produce appealing colors, flavors, aromas, and textures.

In the United States food laws have been designed to permit the use of such chemicals in food under conditions judged to be safe. These chemicals are not considered adulterants or contaminants and are classed as intentional additives.

Environmental contaminants include substances from natural sources or from industry and agriculture. Many naturally occurring contaminants in food are of microbiological origin and consist of harmful bacteria, bacterial toxins or fungal tox-

*For a more in-depth discussion of this topic see *Environmental Contaminants in Food,* Office of Technology Assessment, U.S. Congress, December 1979.

ins. The second category of environmental contaminants includes organic chemicals and heavy metals.

Environmental contamination of food is the result of our modern, high-technology society. The United States produces and consumes large volumes of a wide variety of substances, some of which are toxic. It is estimated that 70,000 chemicals may currently be in commercial production in the United States and that sO of these chemicals are manufactured in quantities greater than 1.3 billion pounds per year (32). During the production, use, and disposal of these substances, there are opportunities for losses to the environment.

Chemicals contaminate foods through different routes depending on the chemical, its use, and source of contamination. A pesticide becomes an environmental contaminant when it is present in foods for which the application or use of the substance has not been approved. Improperly fumigated railroad cars, trucks, ships, or storage buildings used for the transport or storage of human food or animal feed are sources of contamination. The interiors are sprayed or fumigated with pesticides, and if not sufficiently aired, contamination of the food or feed occurs.

Polychlorinated biphenyls (PCBS) were widely used in transformers and capacitors, as heat transfer fluids, and as an additive in some dyes, carbon paper, paint, pesticides, and plastics. PCBS occur in food as the result of environmental contamination leading to accumulation in the food chain, direct contact with food or animal feeds, or contact with food packaging materials made from recycled paper containing PCBS (35). Several comprehensive literature reviews have been published detailing the acute and chronic toxic effects of PCBS in animals and humans *(32).*

Displacement of Labor/Shifts in Employment

The adoption of mechanization technology in the marketing sector has increased labor productivity, but it has also displaced labor and caused shifts in employment. Moreover, new product development, although beneficial to consumers, may have adverse effects on others. For example, following development of margarine from vegetable oils, butter was to a great extent replaced by margarine. Consumers benefited from this development through lower cost of food and potentially better health, but it was disadvantageous to the dairy industry. However, jobs lost in butter manufacturing plants became jobs gained in margarine plants, and dairy farmers, at least in the Midwest, now can produce soybeans as a cash crop to provide the oil for margarine production. Future developments and consumer acceptance of "synthetic" milk made from vegetable proteins and fats also may have an adverse effect on dairy farmers, as the development of meat analogues based on vegetable proteins would have on the meat industry. The magnitude of such effects will depend on the demand-supply relationships for these products when competitive products become available (14).

Burdens on Consumers

Some burdens from PHTME research have been placed on consumers. As noted earlier in this chapter, postharvest technology research has resulted in some products that actually contribute to nutritional problems. For example, high-calorie, low-nutrient snack foods and food substitutes are of lower nutritional value than the foods they replace. Nutritional value needs to be an integral part of food quality, because an increasing proportion of the food supply is modified by postharvest technology.

Among the rapid changes that PHTME research has brought to the processing and packaging of food, the use of chemicals in these processes is looked on with disfavor by certain segments of society. Others eschew highly processed food products in favor of more "natural" foods. Food attitudes are deeply rooted even in a technological culture such as that prevailing in the United States.

During the last three decades packaging of food has undergone major changes. In bottling, for example, there has been a shift from use of refillable glass bottles to the use of nonreturnable glass and plastic bottles and metal cans. **A** result of this trend has been that discarded food containers have become significant components of both litter and municipal solid waste (31). In addition, economies of scale in bottling and transportation, especially using lightweight nonreturnable containers, have favored a trend toward centralization of processing and bottling with fewer processors and fewer brands available.

Transportation and storage requirements of our mass distribution system have made necessary the development of plant varieties resistant to bruising and with long shelf life. Some sensory qualities were relinquished in order for consumers to have year-round availability of fruits and vegetables.

QUALITY OF PHTME RESEARCH

Quality is an important aspect of all research. While the quality of research is difficult to measure quantitatively, most scientists would agree that essential aspects of quality include a logical research plan, dealing with adequate numbers of samples, reproducing results, recording data so that the material can be understood and evaluated by others, and organizing and conducting research so that it is amenable to statistical analyses.

In the debate between the executive branch and Congress on funding PHTME research, critics frequently point to declining quality of the research as reason for not supporting public PHTME research. The perception of low quality is based on past informal or quasi-formal evaluation methods, including those contained in the so-called Pound Report (20). * A review of the literature failed to find any *formal* methods used in the past for evaluating the quality of agricultural research. Newer, more formal evaluation methods were examined for their usefulness.

Evaluation of PHTME Research Quality

OTA commissioned a study to examine new ways of measuring the quality of PHTME research and to evaluate these techniques *(8).* The study evaluated research quality by examining the number of citations of: 1) postharvest technology patents and 2) postharvest technology articles in refereed (i.e., peer reviewed) journals. The results of the study are discussed further below.

Patent Citations From Postharvest Technology Research

The objectives of postharvest technology research programs are generally stated in terms of the development of new and improved products, testing of food and food additives. Much of this research will produce new technology which is patentable, so in evaluating the quality of postharvest technology research it is important to look at patents in postharvest technology areas granted to public agencies and private firms.

Even though patents provide a suggestive measure of innovative activity and quality, at least two important problems with using patents as such a measure should be noted. One problem is that a patent does not necessarily represent a discrete step forward in the innovation process, nor is the extent of its contribution directly indicated by the patenting process. The "quality" of a patent—whether measured by the research behind it, the creativity of the invention, its economic value, or the clarity of its exposition—varies widely. The Patent and Trademark Office does not make—in fact, is forbidden to make—any evaluation of an invention's contribution to the current stock of knowledge, beyond its judgment that the invention is original (i.e., has not previously been patented).

The second problem with using patents as a measure of innovation reflects the process of patenting itself. The cost of the patenting process, the "appropriability" of the returns from an invention, the prospects of litigation, and incentives to patent vary over time. Thus, the number of patents granted will fluctuate regardless of innovative activity. Also, the procedural attributes of a patent (e.g., the number and kinds of claims allowed,

● For a detailed discussion of the Pound Report and other reports see An *Assessment of the United States Food and Agricultural Research System* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, *1981).*

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the number and kinds of patents an examiner cites in his or her examination) may vary somewhat from examiner to examiner, from class to class, as well as from time to time as the Patent and Trademark Office changes its directives. Thus, time series analysis of patents cannot claim to hold all variables in the patenting process constant. For these reasons, the evaluation of patenting activity over time must be interpreted as a broad study of trends rather than a precise analysis (8).

Given these caveats, the study of patenting can be set in a general context. The investigators recognized that patenting was only a partial measure of the output of postharvest technology research, but a very important one. Furthermore, since public postharvest technology research is conducted in the presence of rather large private investments in postharvest technology research, the public and private research should be related. High-quality public postharvest technology research should produce pilot inventions. Public patents should be cited frequently by subsequent private patents as the private sector conducts further research. Public publications should also be cited by subsequent private publications and patents.

Detailed data was collected for the years 1966-68 and 1977-79 on all USDA patents in four postharvest technology research fields (food, textiles, other chemicals, other), and on a sample of 80 private U.S. firms and 61 patents to foreign firms in two of these fields (food and textiles). Information was obtained on the class of patent, on the patents and other references that were cited by patent examiners as "next best art,"* and on the number of times a patent was subsequently cited by other patents.

Most of the U.S. patents in postharvest technology were found to be from private firms. USDA labs accounted for only 5 percent of representative postharvest technology patenting. SAES accounted for even fewer patents. The number of patents per dollar expended on research is higher for USDA than for SAES. No comparative data exists for private research, but because of the importance of a patent to the private sector a crude estimate is that the number of patents per dollar of research is substantially higher for the private sector than the number for the public sector.

A high proportion of public and private postharvest technology patents were found to be subsequently cited in other public and private patents. Of food patents granted in 1966-68, only 22 percent of the USDA patents and 30 percent of private patents were not subsequently cited. For textile patents, only 34 percent of the USDA patents and 18 percent of the private patents were not subsequently cited in the same time period. Private patents in both areas were cited slightly more often than USDA patents, but the data suggest that most patented innovations do contribute to technology improvement.

The data also showed that 28 percent of the patents cited as "next best art" for USDA patents in *1966-68* were other USDA patents and that *35* percent were other USDA patents in 1977-79. Domestic-origin private patents cited USDA patents as next best art 19 percent of the time in 1977-79. The latter finding indicates that USDA patents were a significant part of the invention structure of the private sector. Foreign-origin patents cited USDA patents less frequently. USDA patents also cited fewer total patents than either U.S. private or foreign patents.

It is difficult to draw general conclusions regarding research quality based on patent data alone. Nevertheless, the standards of patentability technique are applied outside the agricultural research system as well. This wider use of the technique involving patent data lends support to the method's credibility.

Publication Citations of Postharvest Technology Research

A large part of public postharvest technology research does not lead directly to patented inventions, but instead provides research potential, which may subsequently lead to inventions and technology. One measure of output of this research is publications. With data on publications that have been subject to quality screening, it is possible to undertake analysis of differences in productivity for different research environments and different time periods. However, good data

● "Next best art" is the citation for a patent that is closest to the one under consideration. Such a citation indicates the patent under examination represents an identifiable step forward.

on quality-screened publications are difficult to obtain. Since publication data reported in data files generally are not standardized for quality, it was concluded that citations in referred journals were a superior measure of quality.

The number of citations is an index of the "importance" of a research contribution. Perhaps more importantly, citation data can indicate the usefulness of one research specialization to other specializations. Thus, a case in which public postharvest technology research publications are subsequently cited only by public postharvest technology researchers would be cause for concern. Citation analysis to date has been used little in agricultural research evaluation.

The citation-of-publications study is more comprehensive than the patent study described above in two respects. First, for this study, the investigators obtained an SAES sample in addition to a USDA sample; and secondly, published output is a more complete measure of researcher output than patents are.

Data sources dictated that data be collected by individual researchers. A list of research project principle investigators was obtained from Current Research Information System data for selected USDA and SAES postharvest technology research studies. With this list of names for different periods, the citations abstract was used to collect data on the number of times the publications of these scientists were cited in *1979.* Data were compiled both on citations of papers published fairly recently as well as on citations of papers published in earlier periods. Both publications and citations were "screened" in the sense that major journals in four areas covered by postharvest technology research (i.e., food *science, agriculture, materials science, and other)* were chosen from which to select citation abstracts.

Statistical models were developed to test whether recent citations were related to institutional affiliations—i.e., USDA or SAES. When citations of earlier papers and age of investigator were used as control variables, there was no significant effect of institutional setting on total citations per scientist-year or on citations per publication. When expenditures per scientist-year were included as a variable measuring the support per scientist in terms of equipment, assistants, etc., they did not affect publication per scientist-year, but did positively affect citations per publication and total publications per scientist-year.

Citations of early work were considered to be an index of "personal" productivity or quality of the researcher in question, and these were significant determinants of citations of later work. The diversity of citations (i.e., citations in fields other than the field of publication) was also affected by personal characteristics. Younger scientists have more influence outside their fields than do older scientists, and scientists with high early productivity and narrow influence have narrower current influence.

Conclusions

These two attempts to look at postharvest technology research quality by examining patents and journal citations do not provide conclusive answers about the quality of public postharvest technology research. In fact, one USDA center having the lowest journal citation score had the strongest performance in patenting. These efforts do, however, add to the pool of other less formal and more judgmental evidence on research quality.

The data are consistent with the view that many public postharvest technology researchers may not be aware of relevant research in closely related disciplines and that some public research programs may be poorly organized. However, the data are not consistent with the highly critical view that public postharvest technology research is producing little of value. Public postharvest technology research is providing patents that are subsequently cited by the private sector. It appears to be providing a body of scientific literature that is roughly comparable to that produced in other applied sciences. Furthermore, the SAES system does not appear to be providing research environments that are superior to those provided by USDA in this research area.

Peer Review

Assessments of published output of scientists have been used to evaluate certain aspects of agricultural research, most notably productivity (e.g., 27), but the application of this technique or variations of it for evaluating the quality of agricultural research is fairly recent.

The quality of research is not necessarily a function of numbers of publications or patents that result from the research. The National Academy of Sciences considers peer review probably the best method of estimating quality. Attempting to use the same scientists to evaluate basic and applied research, or research in different disciplines, however, seems hazardous. Estimating quality of any research requires great care.

Peer review should be review of a scientist's research only by researchers within the same general area, discipline, or mission. For example, in the continuum of basic to applied research, peers of scientists working in basic research can effectively review quality of scientists working in similar basic areas of research. Scientists working in applied areas can evaluate quality of other scientists working on similar applied problems.

PRINCIPAL FINDINGS

- Benefits from public PHTME research may include: 1) increased productivity and reduced real cost of food; 2) improved quality, safety, and nutrient content of food; 3) new or improved food products; 4) information for decisionmaking; and 5) information on industry competitiveness.
- The beneficiaries of PHTME research can include: 1) farm producers, through the enhancement of the value of farm commodities and improved marketing services; 2) consumers, through expanded quantity of food products and lower prices and improved quality, nutrition, safety, and convenience; 3) marketing firms, through research results that are available to small and large firms alike; and 4) labor, through increased labor efficiency that provides opportunity for increased wages and salaries without placing an upward pressure on retail prices.
- The majority of the benefits from PHTME research flow to those regions and States with high concentrations of population. However, the bulk of PHTME research is financed by States in the major farm producing regions, with the majority of the research supported by State appropriations. This means that taxpayers in major agricultural States are subsidizing PHTME research for consumers in less intensive agricultural States. When such public benefits have an impact on residents of the Nation, funding for research can be more equitably provided by the Federal Government.
- Publicly funded postharvest technology research seems to provide a body of scientific literature which is comparable with that of other applied sciences. Some past analyses of the quality of public research suggested the research produced little of value (20). Today, however, evaluation based on analyses of patents and publications (8) does not support this appraisal.

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Chapter 5

Role of Public and Private Research Participants

Contents

Chapter 5

Role of Public and Private Research Participants

Throughout the history of agricultural research, no fixed pattern has developed with respect to the kinds of research performed by the U.S. Department of Agriculture (USDA), State agricultural experiment stations (SAES), and industry, and no principle has emerged to determine the role of each. Decisions as to where research is done in the public sector invariably have been decided ad hoc by discussion and agreement among the concerned parties. The administrative diplomacy required to reach such agreements has reached high levels of complexity in USDA and SAES. Such decisions frequently are arbitrary, expedient, inconsistent from year to year, and more influenced by pressures of the moment than by uniform, long-range guidelines or principles (1). In the absence of an accepted rationale for doing differently, these practices will likely continue.

It should be possible, however, to arrive at a rational and practical plan for assignment of roles to those who conduct postharvest technology and marketing economics (PHTME) research. Admittedly, whatever guidelines are determined must be agreed to. However, once articulated, made public, and used, a plan and guidelines would make clearer to all concerned the basis and logic of certain program decisions, encourage USDA and SAES to focus on the roles expected of them, and permit periodic reexamination over time. Ideally, application of the plan and working guidelines derived from it should result in a sufficiently clear delineation of roles that uncertainties concerning where research should be conducted and how it should be funded would be the exception rather than the rule. This chapter presents an analysis of the roles of participants in PHTME research and provides guidelines for delineation of roles among participants.

PRIVATE SECTOR DOMAIN

Although different segments of the agricultural industry perceive their roles differently, most are motivated by economic incentives. If management can foresee that the private rate of return is sufficient, funds are set aside for the research program. As discussed in chapter 4, industry research may result in benefits for both the private sector and society.

PHTME research in private industry tends to be profit oriented. In the food processing sector, such research primarily takes the form of new product development and new applications for products. This includes but is not limited to: 1) product line extension, such as new flavors, colors, package size, or minor variations introduced to supplement existing products; 2) development of existing products, such as modifications in the formulation, minor improvements in processing technologies, packaging, etc.; and 3) nonfood uses of farm products, such as for energy, lubricants, etc.

In the food distribution sector, the profit orientation includes developments such as improved truck-trailer design and use to lower transportation costs, development of railroad cars and containers for improved quality preservation, and electronic checkouts in retail stores to improve labor productivity.

Profit-oriented research by private industry also includes economics research. Demand and supply forecasting are used particularly by food processing companies to aid in decisionmaking on purchasing inputs so that the firm's costs are minimized. Also used are feasibility studies and market surveys.

In delineating the role of the private sector in PHTME research, certain distinguishing characteristics of private sector research in foodprocessing, handling, and marketing should be considered. * *First,* most private sector research tends to be focused on short-term applied problems for which there is an expectation of an acceptable return on the research investment. *Second,* it is unlikely that longer term basic inquiry into how biological, economic, and social systems function would be picked up by the private research sector if it were dropped by public research agencies. *Third even* though there may be substantial social benefits from private research activities through spillover effects, private industry generally is not concerned with concepts of consumer surplus or net social benefits from their research endeavors. *And fourth,* most private firms are reluctant to reveal knowledge that might cause existing technologies or processes to become obsolete prior to extracting the flow of economic returns from past investments in these techniques. Thus, an incentive exists to delay publication of knowledge possessing this potential impact, even if the research might have been carried out partly under the auspices of public funding.

Based on the above, the areas of PHTME research that are or should be *primarily* in the private sector domain are: 1) processes and techniques that are patentable and accrue into the capitalization of the firm, 2) research to meet Federal and State regulations, and 3) research to maintain or gain clientele.

Research on Patentable Processes and Techniques

Research and development pertaining to patentable processes and techniques is probably the most clear cut in terms of private sector involvement. Such research most nearly fits the one characteristic of private sector research discussed earlier—i.e., it is focused on short-term applied problems for which there is an acceptable return on the research investment.

Industry research on patentable processes and techniques commonly leads to gains for the firm and industry in excess of losses to society. * This observation is particularly applicable in the case of mechanization research, which accounts for a large part of this research activity. Much mechanization research has been induced by long-term increases in the price of labor. The gains to the firm or industry conducting such research often substantially outweigh the losses to workers (s).

The private sector has been an efficient source of new mechanical technologies in postharvest technology as well as in agriculture in general. Even when public funds have been expended in the mechanical technology area, many believe that the firms would have developed the technology without the public sector involvement. The demand for commercial development has appeared to be more important than the public research effort (4).

In late *1979,* former U.S. Secretary of Agriculture Bob Bergland, responding to a concern about public sector support for mechanization research, announced that USDA would no longer support research leading to the "replacement of an adequate and willing work force with machines. " Bergland stated that USDA would not put Federal funds into research when a careful review and analysis clearly indicate: 1) that the direct and immediate benefits will go to a limited number of locales while neither serving the national interest nor benefiting the general public; and 2) that the research poses a direct or an indirect threat to social stability, the national resource base, the environment, the national security, or the economic well-being of a significant number of citizens. Bergland immediately qualified these remarks by indicating that he had no objection to research and development designed to ease the drudgery of work rather than to replace workers with machines, but this distinction is not feasible either technically or analytically (4).

Bergland's statements gave impetus to a badly needed debate concerning the appropriate roles of public and private sector research. Supporters of public sector mechanization research have fre-

● These characteristics were identified in the unpublished USDA assessment "Postharvest Technology Research Assessment, " March 1979.

'It is recognized that there is some research, such as improvements in products, which has few, if any, losses to society.

quently attempted to interpret Bergland's remarks as an attack on mechanization rather than on the more fundamental question of the rationale for public sector funding of this research. Opponents of public sector mechanization research apparently are less concerned with the displacement of labor than with the failure of public institutions to consider laborers as well as farmers, processors, and retailers as part of their clientele and the failure to provide parity of treatment for laborers (4).

The implication of the mechanization debate for public and private research seems reasonably clear, The private sector has been an effective source of new mechanical technology. Lack of knowledge has seldom been a serious constraint on advances in mechanical and patentable technologies, Public research in this area may be justified primarily for its value in training new scientists and to linking biological and chemical research with mechanical technology.

Research To Comply With Federal and State Regulations

A firm operating in the United States must adhere to many Federal and State regulations in order to process and/or market a food product. These regulations include but are not limited to regulations concerning food safety, nutritional claims, shelf life, environmental pollution, and worker safety. A firm may need to conduct research to meet these regulations or mitigate their impacts.

For example, the basic purpose of nutrition labeling of food products is to provide accurate nutrition information to the consumer. Nutrition labeling is a voluntary/mandatory program—i.e., participation in the program is voluntary, but if a firm elects to participate, it must follow a mandatory labeling format and provide the necessary research data to support its label. When a processor makes any kind of labeling or advertising claim about the food's nutritional value or when the food is enriched with any essential nutrients, compliance with the nutrition labeling program becomes mandatory.

Another example of research to meet regulatory requirements is establishing the shelf life of food products. Many States require that manufacturers convey to consumers the length of time the product will maintain its quality, especially for perishable products. To develop these time intervals or dates scientifically, each food manufacturer needs to conduct shelf-stability studies on each product and determine the time at which sensory quality falls below the point of consumer acceptance. Research to comply with such regulations is often referred to as "defensive research."

Research To Maintain or Gain Clientele

A firm interested in maintaining or gaining clientele will conduct or have conducted for it research that is directed toward this end. The most explicit example is in the area of food quality. A firm differentiates itself from its competitors by providing a certain level of food quality. In order to maintain and ensure this quality level, the firm conducts research and analysis throughout the processing cycle. A firm also engages in product development research for the purpose of expanding its product line, further developing its existing products, or finding new applications for its products. A firm may also conduct economic research, such as market surveys, to determine what actions it may need to take to either maintain clientele or to gain new clientele. Significant incentives exist for the private sector to conduct this type of research, because the returns of such research accrue mostly to the firm.

PUBLIC SECTOR DOMAIN

There are certain areas of PHTME research which logically fall to the public sector. Public sector research efforts are in both basic and applied PHTME research. Public sector support of basic research generally benefits both society and the private sector. Because the results of basic research are difficult to internalize to any particular private firm, underinvestment in basic research would result without public support.

In the case of applied and developmental research, however, an important issue that arises is the appropriate mix of public and private research investments. The private sector will stand to benefit from public investments in those types of research whose outputs are embodied in private sector products. Examples include the areas of chemical and biochemical research, mechanical research, the development of seed varieties, and food processing and fabrication. Although much of the research responsibility in these areas has been assumed by the private sector, public research activities are also maintained.

Public sector research may be justified on at least three grounds. First, because of the spillover effect, substantial social benefits are derived from a mixture of public and private research. *Second,* in the absence of public sector support, the direction of the research might tend to be biased strongly toward proprietary mechanical and chemical technologies. *And third,* for those situations whereby private research might have a detrimental effect on the structure of the industry (making a competitive structure noncompetitive, or a noncompetitive structure still more imperfect), a mix of public and private research may serve to preserve competition or reduce the amount of market power. The importance of this last basis for public investment in research is that most competitive industries provide a larger quantity of the product at a lower cost to consumers and a higher price to farm producers than would be expected from an uncontrolled monopolistic industry (9).

Because of the ease of imitation and lack of patent enforceability, it is likely that the private sector would substantially underinvest in many marketing economics research activities, Thus, much marketing economics research is supported by the public sector, even in those areas where substantial inducements exist for product development by the private sector. Few marketing firms, for example, conduct much research in aggregate consumer demand for food products. However, public sector research is available to large and small food marketers alike and to farmers and consumers for improved decisionmaking. Because of the difficulty of patenting the information gained by public research institutions, small marketing firms have been able to exist along with large firms. Thus, it has been thought to be in the best interest of society to support public investments in these types of research activities, because the social benefits would outweigh the costs incurred from an uncontrolled monopolistic industry (9).

Based on the above considerations, the areas of PHTME research that are or should be *primarily* in the public sector domain are: 1) research to provide basic knowledge, 2) research to support policymakers and action/regulatory agencies, and 3) research to enhance competition.

Research To Provide Basic Knowledge

Basic research may be defined as activity directed toward the production of new knowledge. The systems may be physical, biological, mechanical, economic, social, or political. Basic research is directed to specifying and quantifying interrelationships in a cause-effect context. It is concerned with theoretical concepts, the formulation and testing of hypotheses, and with enunciating laws and principles. Basic research is almost universally transferable.

Basic research represents the principal mode for developing the knowledge base necessary for future scientific and technological breakthroughs. These in turn frequently lead to significant economic benefits and improvements in social welfare. Within the academic sector, basic research also serves an important function in education of graduate students.

The public sector clearly has responsibility to fund and conduct some basic research. The private sector also supports basic research by funding and conducting it. Approximately 10 percent of agricultural industry's research and development funds are for basic research. However, little incentive exists for the private sector to increase this amount. For the most part, the results to be obtained from basic research are unknown and unquantifiable, and the payoff quite far in the future. This provides little incentive for private basic research. Further, even if there were adequate incentives, the results of the research would be proprietary. Thus, for the advancement of science and future technological breakthroughs, the public sector, which makes known the results of basic research to the public, has a clear role in providing the fundamental knowledge on which these breakthroughs are based.

Research To Support Policy makers and Action and Regulatory Agencies

There are many users of research within government. Policymakers, both in the executive and legislative branches of government, are demanding more information from research and policy analysis before making decisions. In the PHTME area, policymakers at the Federal level include the Secretary of Agriculture, Secretary of State, Secretary of Treasury, Secretary of Health and Human Services, and the respective legislative and appropriations committees in Congress. Decisions these Federal policymakers need to make include the appropriate level of support prices for farm products, the level of U.S. farm product exports, the imposition of tariffs on imported food products, and the amount of the Federal budget that will be devoted to food and agricultural concerns. Information developed through research is needed for policymakers to be able to make informed decisions.

Action and regulatory agencies depend on research results in implementing their regulatory and programmatic responsibilities. In the PHTME area, these responsibilities include decisions on the use of food additives, the safety of irradiation of food as a processing technique, the detection of nitrosamines, chemical methods for detection and measurement of bacterial contamination of food, antitrust cases involving food companies, the effectiveness of marketing orders, and necessary regulations in commodity trading. Equally important to these agencies is research that analyzes the impact of these regulations. Action and regulatory agencies need to be informed of the regulations' benefits and costs. This information is useful in guiding the agencies in modifying or eliminating existing regulations, or establishing new regulations.

In the absence of research in the above areas, policymakers and action and regulatory agencies would not have an adequate knowledge base to make appropriate decisions. There seems to be little argument that research is needed to support these areas. The public sector is considered the best source for this research since it conducts research where the benefits accrue to parties other than those supporting the research.

Research To Enhance Competition

A major function of the U.S. Government is the maintenance of a free and competitive economic system. The system requires protection from monopolistic practices that would thwart competition. Public research can contribute to the maintenance or enhancement of competition in the agriculture production and marketing sectors. * For example, the flow of new technology from public research and development has contributed to competitive behavior in the seed and fertilizer industries (2). This is because the results of public research are disseminated to the public, as opposed to privately supported research, which is proprietary and has the potential of extracting monopoly profits to some degree over time.

A basic tenet of government is that it should not do what the private sector can or will do. This *tenet must be balanced as the private sector becomes more engaged in research and development while it becomes more monopolistic in character.*

The dilemma is particularly evident in applied and developmental research. For those areas of the marketing system where firms lack resources in terms of funds, scientific manpower, and facilities to conduct their own research, public sector research can provide new technology that not only increases productivity but enhances competition. Much of this research is of an economic/engineering nature and involves working with individual firms to test and evaluate the application of a technology to **an** industrywide problem.

*Public research sometimes does not contribute to the maintenance of a competitive structure; in some cases, it increases economies of scale. More public PHTME research needs to consider its influence on market structure and, hence, on competition.

The results of the evaluation are then publicized for the benefit of all firms in the industry. When new technology is adopted by a firm that results in cost savings, competition causes other firms to adopt the new technology rapidly.

For example, partial or full automation has been made possible for small dairy processing plants as a result of public research. Prior to this research, automated procedures were available only as complete package deals from equipment manufacturers. Research findings made it feasible for small plants, which cannot afford full automation, to purchase and install the parts of the system advantageous for their volume. An estimated annual reduction in labor costs of $50 million is possible, if the approximately 1,000 small plants involved adopt the research findings (7).

Much of public marketing economics research is directed toward providing information that, when used in decisionmaking, contributes toward economic competitiveness. Such research ranges from computers in electronic marketing of farm products to studies of the effects of policy instruments to maintain or enhance competition. For example, competitive marketing conditions do not prevail for many cattle producers. Most livestock markets are small, with high selling expenses and less than desirable buyer concentration. The vast majority of cattle feeders are too small to attract bids directly from a number of competing buyers. Likewise, the small number of buyers present in many auctions and terminal markets often leads to fraternalism among buyers, enhancing the potential for buyer collusion. Most producers lack timely information on prices in alternative markets and typically sell too few cattle to make good use of what market information they do obtain. One alternative to this problem is public research on conceptualizing and developing electronic markets. * This allows producers to reach alternative markets with the potential to expose market offerings of each seller to competitive bids from every buyer and the bids of each buyer to every seller. It can potentially provide instantaneous information on prices and other terms of trade and facilitate direct shipment of cattle from seller to buyer. Research indicates that electronic markets can perform these functions more rapidly than the conventional system, with greater accuracy and at a lower cost while increasing competition among buyers at the same time (3).

At the other end of the spectrum of research to enhance competition is public research that: 1) determines the competitive factors which affect market performance in the food and agricultural sector, and 2) measures the effectiveness of policy instruments to maintain or enhance competition. Such public research is vital to better understanding of what forces affect market performance and to determining the effect such policies as antitrust laws and enforcement have on competition.

* Electronic markets are so named because they use modern electronic devices such as telephones, computers, teletype networks, and TV-like two-way communication devices to create a market.

JOINT PUBLIC AND PRIVATE SECTOR DOMAIN

Some areas of PHTME research exist in which there is reason for research activity for both the public and private sector. These are areas in which the incentives for private research are not adequate, because many of the gains from private research in these areas are captured by other firms and consumers. The public sector may need to be involved to ensure the conduct of research from which the social gains exceed the private profit.

Research on New Food Sources and Their Development

This area is fertile for research from both the private and public viewpoint. From the private sector side, discovery of new food sources can possibly mean new and less expensive ingredients in food processing or more efficient usage of byproducts of the manufacturing operation. The public sector has an interest because of the concern about potential global shortages of food and concern for environmental pollution.

A good example is the improved utilization of cheese whey, an important large-volume byproduct in processing cheese whose disposal presented environmental and physical problems. The private sector incentive for research on cheese whey was its profit potential. The public sector conducted research on cheese whey because of concern for the environment and as a potential means of increasing the food supply.

These public and private research efforts had several results. First, liquid sweet whey could be combined with full-fat soy flour or soybean isolates to yield a free-flowing powder of good nutritive value. The whey-soy blend was commercially used by the baking industry, where it demonstrated better functionality than did nonfat dry milk in doughs processed by continuous baking equipment. Second, spray-dried whey protein concentrates could be incorporated into commercial soft drinks and drink powder without detectable change in flavor or appearance and with improved nutritional value from added protein. Third, low-lactose products from milk and whey could be readily prepared with conventional dairy plant equipment. Such products are suitable for consumption by lactose-deficient individuals (8).

Improved utilization of cheese whey has significantly reduced environmental pollution in many cheese-producing areas, and has increased economic returns to processors. The development of new ingredients has increased the variety, nutritional quality, and storage stability of foods, especially convenience foods, available to U.S. consumers. Dairy products aimed at a new consuming population, lactose-intolerant consumers, are commercially available in some areas. Development of whey-soy drink mix as a milk analog provided economic benefits to the processors while meeting the demand for this product in developing countries.

Research on Naturally Occurring Food Contaminants

Prevalent naturally occurring toxic contaminants in the food chain are mycotoxins. These are substances produced by molds under special circumstances; some are carcinogenic in animals. The best known mycotoxin is aflatoxin, which lowers feed efficiency and weight gain in livestock and in larger doses can cause death. This effect on livestock provides an economic incentive for the private sector to conduct research on mycotoxins.

When aflatoxin-contaminated feed is fed to milk cows, a related carcinogen can be found in milk. In humans, there is circumstantial evidence for its involvement in causing liver cancer. This provides the incentive for public sector research efforts even though the private sector is interested in the safety issue too. Certainly no company that intends to stay in business wants to produce an unsafe product. But whereas the individual firm is only concerned with that portion of the crop under its control, the public sector must be concerned with the safety of the entire crop.

These research efforts indicate that aflatoxin in corn, which is not detectable under ordinary conditions, can now be detected in less than 5 minutes by a fluorescence test. * Once detected, the amount in the sample can be determined by analytical procedures. The public sector held workshops for corn handlers (farmer elevator operators, millers, and processors) on detecting and measuring the toxin. These tests offer anyone in the marketing chain added protection against the financial hazard of buying contaminated corn. They also provide protection for the general public by reducing the chance that aflatoxin will enter the food chain.

* Research is continuing on this technology to improve its detection capability. Concern exists that ultraviolet gives too many false positives and thus is not precise enough.

Research on Yields in Relation to Productivity v. Nutritional Components

This area of research relates to the differing orientation of the private and public sectors. The private sector's first priority is to conduct research that will increase the output from a given input. This research can make more food available through improved processing, upgrading products, preventing waste, and providing for utilization of products previously not considered usable.

The public sector, while interested in increasing productivity, is also concerned with improved nutrition and health. The primary purpose of food is to provide nutrients required for body functions. With the industrialization-commercialization of the food and agricultural sector, ensuring the nutritive value as well as the safety of food has gained in importance because consumers are further removed from primary production. Processing and preservation technologies that expand output can improve the nutritional value of food, retain it in a stable condition, or cause it to deteriorate. The consuming public cannot know immediately which of these has occurred. Little incentive exists for the private sector to take this into account when attempting to increase yield or supply of food. Thus, the public sector also needs to be engaged in this type of research with multiple objectives.

USDA AND SAES ROLES

During the early history of the development of SAES, them was some concern about the relationship of the research stations to the land-grant colleges. There was even greater concern about the acquisition of Federal funding through USDA for support of SAES, free from excessive domination by the Federal Commissioner of Agriculture. The Hatch Act of 1887 resolved many of these issues and provided for a high degree of State autonomy in designing and conducting research.

Additional legislation providing support for the establishment and strengthening of SAES clearly recognizes SAES as entities distinct from the land-grant colleges. In the early years, the SAES were concerned almost totally with State and local research problems. As the stations grew and additional acts were passed by Congress providing wider use of funds, however, their research broadened to include regional, national, and international activities.

Meanwhile, USDA has developed a wide network of research laboratories, stations, and activities that not only includes national, regional, and international activities but at times involves strictly local problems.

This broad base for application of Federal and State resources to research problems has led some, including Congress, to question the degree of research planning and coordination that exists, especially at the top levels of administration. There seems to be considerable duplication of effort and vying for funds—including PHTME research—and Congress and other interested groups have increasingly been concerned *(6)*.

Most agricultural research administrators—whether SAES, USDA, or other—recognize there is not unanimity of thought on how best to manage and carry out U.S. agricultural research and the appropriate roles of the various actors for an effective and efficient system.

An important consideration in establishing these roles in research is the source of funding for research in relation to the beneficiaries of the research. USDA is funded primarily by Federal funds and SAES by State, Federal, and private funds, and the roles of these research participants are generally more complementary than competitive. Under the Hatch Act of 1887 and the Research and Marketing Act of 1946, discussed in appendix D, SAES conduct research on local, State, and regional problems (cooperatively with one or more States). SAES have no direct mandate to conduct research on problems of national importance, although research on State and regional problems may contribute to the solution of national problems. USDA has responsibility for assuring the conduct of postharvest technology research directed at problem-solving in the national interest, but to some extent must address the local and regional aspects of national problems.

The allocation of research responsibilities distributes itself very logically among the major performers. The Federal Government, either intra- or extramurally, must give highest priority to problems of national significance, and must, as a part of this responsibility, maintain an awareness of and take into account the contributions of the States and private industry toward national objectives. SAES, insofar as Federal funds are concerned, must give highest priority to concerns of the State and to those of the region of which the State is a part.

These roles have historical precedent and are logical today. As more is known about the beneficiaries of this research and are better able to quantify the relationships between funding source and beneficiaries, there is strong evidence for major Federal input to PHTME research, because the benefits of such research go to the general public and not any one State or region. USDA should work as a partner with SAES to achieve complementarily and cooperate with private and other public universities and industry to coordinate its own contribution to achieve national goals most effectively. Both USDA and SAES should collaborate when appropriate to assist the research performance and respect the integrity, role, and decisionmaking responsibilities of each institution.

In a more general sense, the Federal role in PHTME research should include:

- providing scientific leadership in the identification of research needs, setting the national research priorities, and in developing plans and programs to address those needs and priorities;
- supporting SAES in conducting research on agricultural problems of special concern to a specific locale, State, or region;
- providing substantive leadership and coordination to facilitate the flow of information among States and between the States and the Federal Government and to identify opportunities for and conduct or support research with a regional and national emphasis;
- assuring the development of new fundamental knowledge on which future advances depend, by supporting and conducting research in basic agricultural science; and
- maintaining a Federal research capability responsible for conducting basic and applied research in support of unique Federal missions such as research for regulatory and action agencies and research that enhances competition in the food and agricultural sector.

PRINCIPAL FINDINGS

- There is a role for public and private research efforts in PHTME research.
- The primary domain of private sector PHTME research is: 1) research on patentable processes and techniques (including mechanization research), 2) research to meet Federal and State food regulations, and 3) research to maintain or gain clientele.
- Public sector PHTME research should concentrate primarily on: 1) basic research, 2) research to support policymakers and action and regulatory agencies, and 3) research that enhances or maintains competition.
- Both public and private research efforts are justified in areas such as: 1) research on new food sources, 2) research on naturally occurring food contaminants, and 3) research on yields in relation to productivity versus other objectives.
- The Federal role in PHTME research includes providing leadership in identification of national research priorities and conducting supporting research with a regional or national em-

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phasis; supporting SAES in conducting research of special concern to a locale, State, or region; assuring development of new fundamental knowledge by supporting or conducting basic research; and maintaining a research capability for conducting basic and applied research in support of unique Federal missions.

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Chapter 6

Policy and Management of USDA Research Programs

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Policy and Management of USDA Research Programs

As the research mission in postharvest technology and marketing economics (PHTME) research becomes more varied, as new priorities vie for attention, and as funding becomes more stringent, the need arises for finding ways to strengthen leadership standards and performance at all levels. Accomplishing such goals will require a thorough and honest analysis of policy and management within the public sector PHTME research program.

This chapter focuses on the four research agencies within the U.S. Department of Agriculture (USDA) that are primarily responsible for conducting or funding PHTME research: 1) the Agricultural Research Service (ARS), 2) the Economic Research Service (ERS), 3) the Agricultural Marketing Service (AMS), and 4) the Cooperative State Research Service (CSRS). Three of these four agencies report to different Assistant Secretaries in USDA. This situation makes it difficult to plan and coordinate PHTME research activities. These agencies are experiencing new challenges and may need to consider different management organizations and policies in order to maximize their research potential.

AGRICULTURAL RESEARCH SERVICE

ARS reports to the Assistant Secretary of Science and Education within USDA. The agency's mission is to develop through basic, applied, and developmental research, new knowledge and technology which will result in an abundance of high-quality, nutritious, reasonably priced food and other agricultural products to meet domestic and world needs while maintaining natural resources and environmental quality (7).

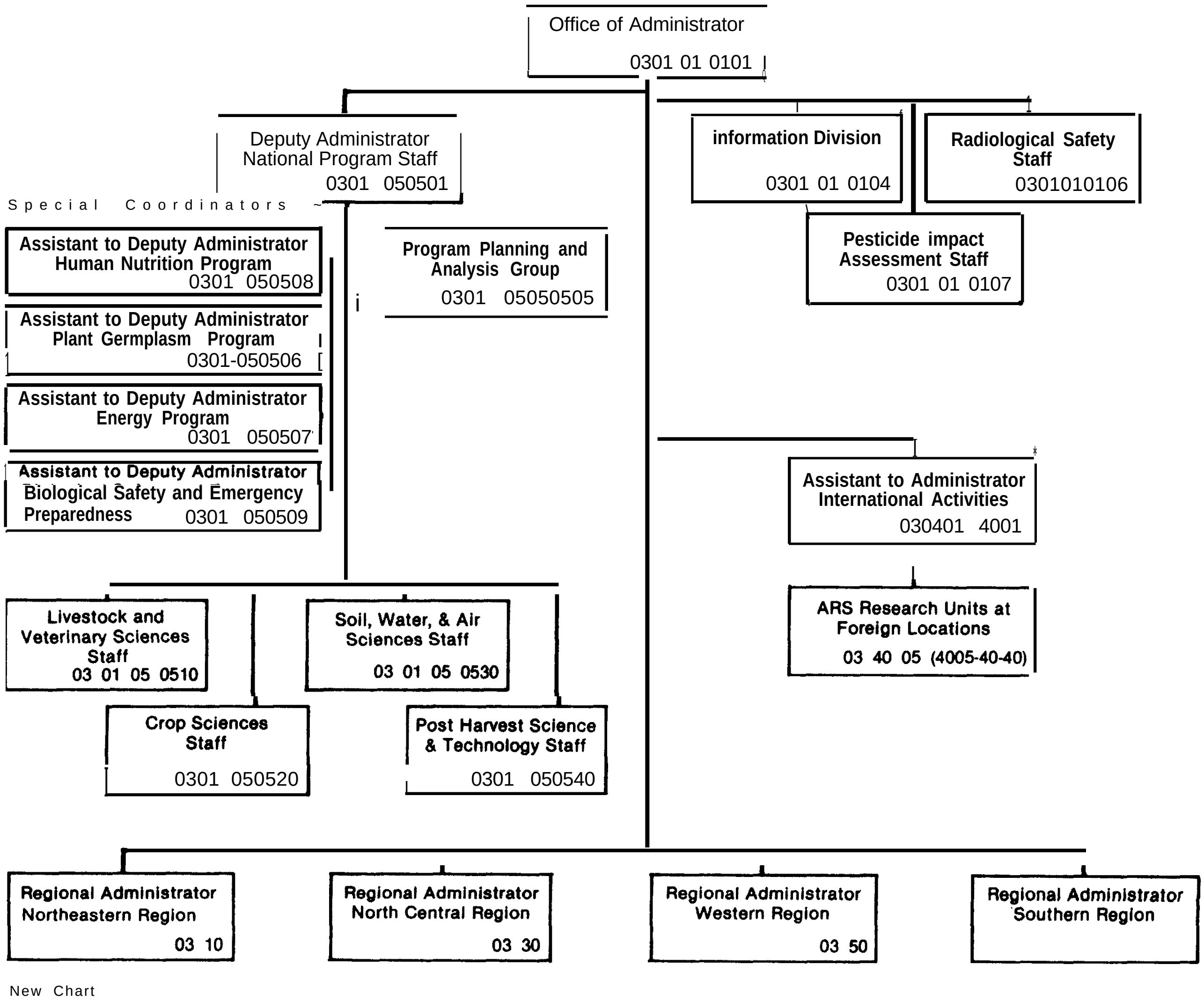
The research of ARS encompasses animal and plant protection and production; and the use and improvement of soil, water, and air; the processing, storage, and distribution of farm products; and human nutrition. Research activities are carried out at 147 locations nationwide, in Puerto Rico, the Virgin Islands, and in 8 foreign countries. Much of this research is conducted in cooperation with State partners in the universities and SAES, other Federal agencies, and private organizations.

ARS was reorganized in 2972 along regional lines, ostensibly to improve collaboration and efficiency in the relationship between USDA and SAES (4). The present organizational structure of ARS is shown in figure 28. Four regional administrators report directly to the Administrator of ARS and are responsible for activities in each of four geographic regions: Northeastern, North Central, Southern, and Western. The organization of ARS regional offices is shown in figure 29.

Responsibility for ARS research programs is now highly decentralized. The focal point for day-to-day management of the various national research programs assigned to specific field locations is the regional/area structure comprised of 4 regional offices, 14 area offices, and 7 major research centers. Postharvest technology research is concentrated in the 4 regional research centers, at the Richard B. Russell Research Laboratory, and in 40 smaller laboratories within the area/research center line management structure.

A national program staff assists the ARS Administrator in planning, budgeting, and management of the overall ARS research program, *but has no line authority to make decisions concerning* the allocation of resources, Previously, national program investigation leaders with line responsibility and authority could relate to an individual State or group of States and then transcend these boundaries and furnish cohesive and

Figure 28.—Organization of the Agricultural Research Service



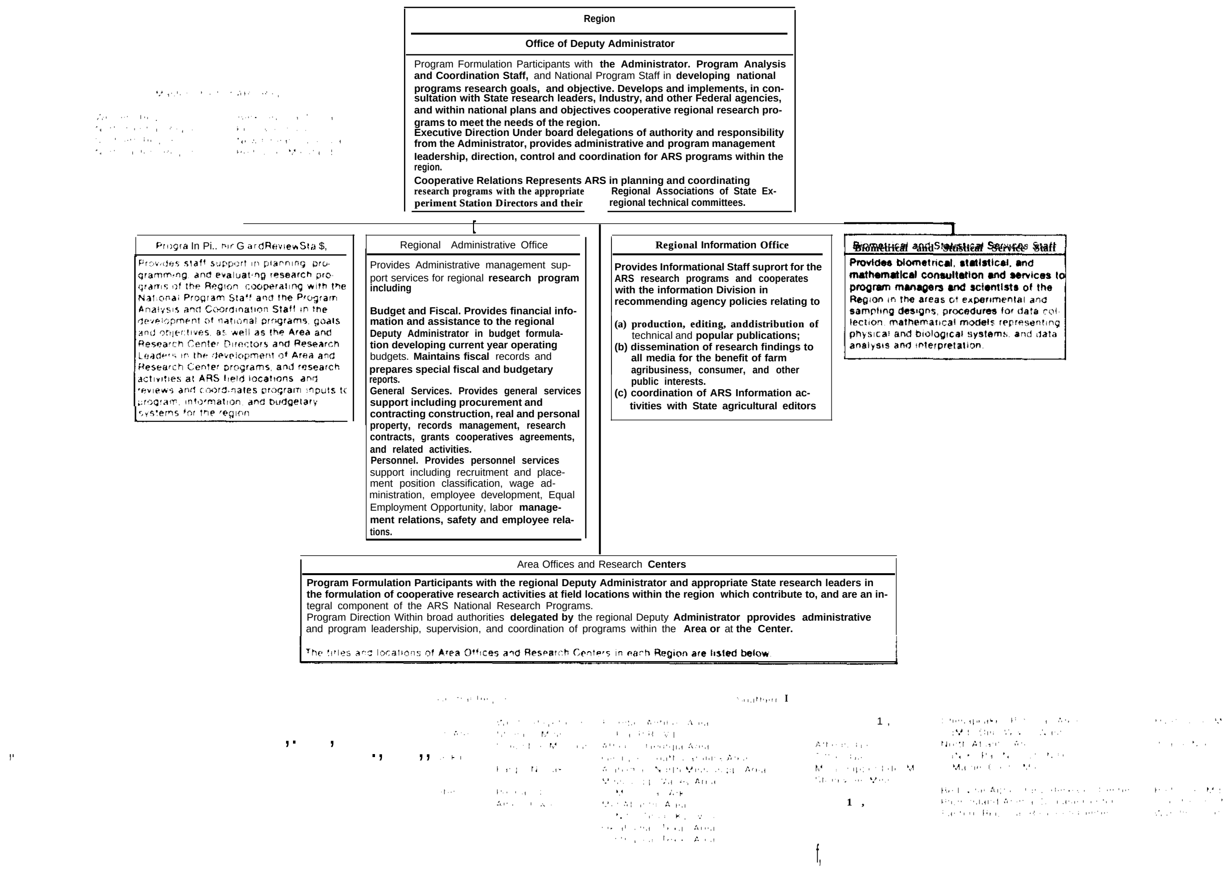
MISSION Development through basic, applied, and developmental research, new knowledge and technology, which will Increase an abundance of high quality nutritious, reasonably priced food and other agricultural products to meet domestic and world needs while maintaining natural resources and environmental quality This mission focuses on the development of technical information and technical products which bear directly on the needs to (1) manage and use the Nation's Soil, water, air, climate resources and improve the Nation environment, (2) provide an adequate supply of agricultural products by practices that will maintain a permanent and effective agriculture, (3) improve the nutrition and well-being of the American people, (4) improve living in rural America, (5) strengthen the Nation's balance of payments, and (6) promote world peace

SOURCE United States Department of Agriculture Agricultural Research Service, 1982

coordinating services and functions on a nationwide scale. The reassignment of these individuals to national program staff positions *without* line authority, however, has diminished the national perspective and national technical leadership in the agency's postharvest technology and other research efforts.

Postharvest technology research is represented at the level of the national program staff by a separate staff component on postharvest science and technology (now called commodity conversion and delivery), but is not similarly represented at the regional and area level. Regional administrators most likely would not possess the technical

Figure 29.—Organization of ARS Regional Offices



SOURCE U.S. Department of Agriculture, Agricultural Research Service, 1982

expertise needed to make judgments on the technical components of their varied research portfolio, which may include postharvest technology, livestock and veterinary sciences, crop sciences, and soil, water, and air sciences.

A positive aspect of the present regional organization of ARS is that it provides an environment for interdisciplinary research. This is true as long as a national research focus, as opposed to a local one, exists. However, maintaining a national focus is difficult with the present organizational structure, and there is nothing to prevent the national program staff from being organized along interdisciplinary lines.

ARS regions have little relevance to regional PHTME research problems. These areas correspond to SAES regional areas, which encompass specific States, and were selected to improve coordination with SAES. However, regional research problems generally do not follow State lines. Furthermore, different regional research problems may involve different clusters of States. ARS scientists at the regional centers and 40 field locations do not have the opportunity to work directly with national program leaders in finding the best way for their efforts to become effective and useful parts of the national and regional efforts. Thus, the current focus is on State and local problems. Because the present organization is subject to pressure by local groups that want research on practical problems, the present organization also makes it difficult to emphasize basic research (4). *

*In February 1983, ARS announced the results of an internal review of the agency. ARS developed a long-range plan for research and an accompanying implementation plan. The plan includes an increase in PHTME research effort. In addition, the national program staff has been reorganized in an effort to reduce the high administrative overhead. However, little, if any, change was made in the national program staff's responsibilities.

ECONOMIC RESEARCH SERVICE

ERS reports to the Assistant Secretary for Economics and conducts marketing economics research relating to production and marketing of farm commodities. ERS research includes evaluations of the organization and performance of major commodity subsectors, costs and returns to farmers and marketers, situation and outlook, commodity projections, price spreads, and analysis of U.S. farm commodity programs, and international markets. ERS marketing economics research projects deal mostly with broad questions about relationships among prices and quantities. These projects are aimed at helping public policymakers and others make informed decisions about marketing policies (8).

Marketing economics research is fragmented within ERS. Domestic marketing economics research is largely concentrated in the nine branches of the National Economics Division, which are shown in figure 30. The greatest part of the division's work in this area is conducted by the three National Economics Division branches dealing with various stages of the food system (inputs and finance, farm sector economics, and food economics). In addition, each of the division's three commodity branches (animal products, crops, and fruits, vegetables, and sweeteners) conducts some vertical subsector marketing economics research. Of the three functional specialty branches (economic indicators, agricultural history, and food and agricultural policy), the economic indicators branch has the greatest responsibility for marketing economics research; it conducts research on the marketing bill, marketing spreads, and related topics.

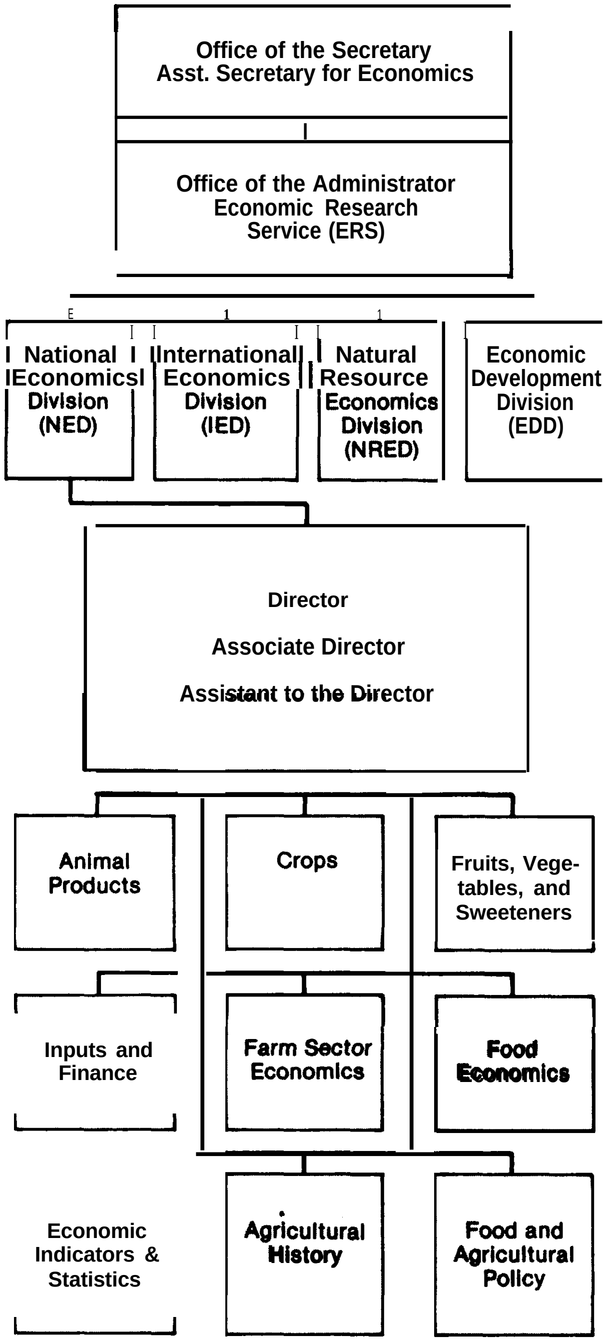
International marketing economics research is conducted by all the branches of the International Economics Division of ERS. These branches are organized geographically. The research they conduct generally is aimed at identifying trends in food demand in foreign countries and drawing implications for export markets in those countries.

Prior to 1973, marketing economics research in ERS was an identifiable and prominent research activity, as noted in appendix D. Since then, the level of support for marketing research has decreased, and the level of research also has decreased. The level of real funding for marketing economics declined from fiscal year 1970 to fiscal year 1980, and the number of scientist-years* devoted to marketing economics research in ERS dropped from 119 to 76 (8).

Changes in the content of the marketing economics research program were significant. Research on new products, merchandising, and promotion, including direct cooperation with the utilization/postharvest technology laboratories of ARS, was substantially reduced. Studies of plant efficiency and interregional competition, which had been a major component of the research in the 1950's and early 1960's, almost disappeared in the 1970's. Subsector studies received major resources in the late 1960's and early 1970's, especially the hog-pork subsector effort. Studies of market organization and structure received major emphasis. In the 1970's, added emphasis was put on studies of regulatory impacts, as the

● A scientist-year is the equivalent of one scientist working full time for 1 year.

Figure 30.—Organization of the National Economics Division of ERS



SOURCE: U.S. Department of Agriculture, Economic Research Service, 1982.

effects of regulation attracted much more public attention and regulation proliferated (8).

In addition to being fragmented within ERS, marketing economics research is also fragmented between ERS and SAES. There is little communication between ERS and SAES concerning the role of each on research in general, or on marketing economics research in particular. As discussed in the 1981 OTA report on the U.S. food and agricultural research system (4), ERS in 1979 convened a national committee of agricultural economics department chairmen and researchers to discuss mutual problems and interests. One issue raised was a perceived misunderstanding about similarities and differences in the role of ERS and university departments of agricultural economics. This lack of understanding was viewed as a barrier to improving the linkages and communication between ERS and universities. A number of stereotypical descriptions indicated the differing perceptions of the group: 1) ERS works on national problems, and universities work on local and regional problems; 2) universities work on micro problems and ERS on macro problems; 3) universities should conduct basic and methodological research, and ERS should conduct applied research; and 4) ERS serves national policymaker clientele, and universities serve farmers and State policymakers.

It is clear that the agricultural economics profession is not in agreement on what the roles are or should be for ERS and the universities. Recently, ERS stated that its role is to concentrate on questions of national concern, leaving the regional and particularly local impacts to the universities (8). However, little unanimity of thought exists on this by the universities, and there is no coordinating mechanism to put it into practice.

During the long existence of the Bureau of Agricultural Economics (1922 to 1953) and since 1961, agricultural economics research, including marketing economics research, has been a separate research component in USDA. (Between the two periods, most of the economics research was integrated into ARS and AMS.) University departments of agricultural economics also are organized separately from other disciplines. One result from this type of organization has been some isolation from the rest of the agricultural research community. In PHTME research, this is especially the case between food scientists and agricultural economists.

The discovery of new knowledge does not come as easily and in such small disciplinary packages as it once did. Modern agricultural research is mission-oriented and interdisciplinary, involving the commitment of large expenditures over time. Yet USDA and land-grant universities with some exceptions are not organized to perform this kind of research (3).

There is little communication and cooperative research work between ERS economists and ARS scientists. In fact, with the exception of some ad hoc groups that meet sporadically, no coordinating mechanism for planning and conducting interdisciplinary research exists between ARS and ERS (4). Within PHTME research, closer coordination and collaboration of marketing economics research in the National Economics Division and the postharvest technology national program of ARS are warranted.

AGRICULTURAL MARKETING SERVICE

AMS, which was established by the Secretary of Agriculture on April 2, 1972, under the authority of the Reorganization Plan No. 2 of 1953, reports to the Assistant Secretary for Marketing and Transportation Services. AMS is an action agency that is responsible for providing services related to consumer protection, agricultural marketing and distribution, and regulatory programs as authorized by law.

AMS administers a market news service that provides information to producers, processors, distributors, and others on supplies, demand, prices, movement, location, quality, condition, and other market data on farm products in specific markets and marketing areas. It also administers several regulatory programs in the areas of standardization, grading, and inspection. At least 95 percent of the AMS budget in the 1980's has been allocated to distributing market news to the agricultural community and to inspection, grading of agricultural products, and other regulatory activities. Other ARS activities include market protection and promotion, wholesale market development, and market supervision and assistance. In the 1980's, less than 2 percent of AMS funds has been devoted to market development,

In addition to its other responsibilities, AMS currently has responsibility for the conduct of studies of the facilities and methods used in the physical distribution of food and other farm products; for research designed to improve the handling of all agricultural products as they move from farm to consumers; and for increasing marketing efficiency by developing improved operating methods, facilities, and equipment for processing, handling, and distributing dairy, poultry, and meat products* (6).

AMS research is aimed toward improving the efficiency of the marketing sector for agricultural products by improving the physical flow, improving productivity, and minimizing rising marketing costs. AMS research tends to be applied research of an economic/engineering nature that involves the application of new technology to marketing problems to demonstrate the potential savings.

To test and evaluate the application of technology to an industrywide problem, ARS often works with individual firms; typically, such firms lack the resources, skills, and funds to do their own research. At the conclusion of the evaluation, the results are publicized for the benefit of

● From 1964 until 1979, AMS did not have a research program. In 1979, selected marketing research functions were transferred back to AMS from ARS. These included the animal research, marketing operations research, and food distribution research laboratories, which were a part of the Agricultural Marketing Research Institute of ARS. For more information on the history of the development of AMS research, see app. D.

all firms in the industry. When an improved method that is adopted by a firm results in costs savings, competition causes other firms to adopt the new technology rapidly.

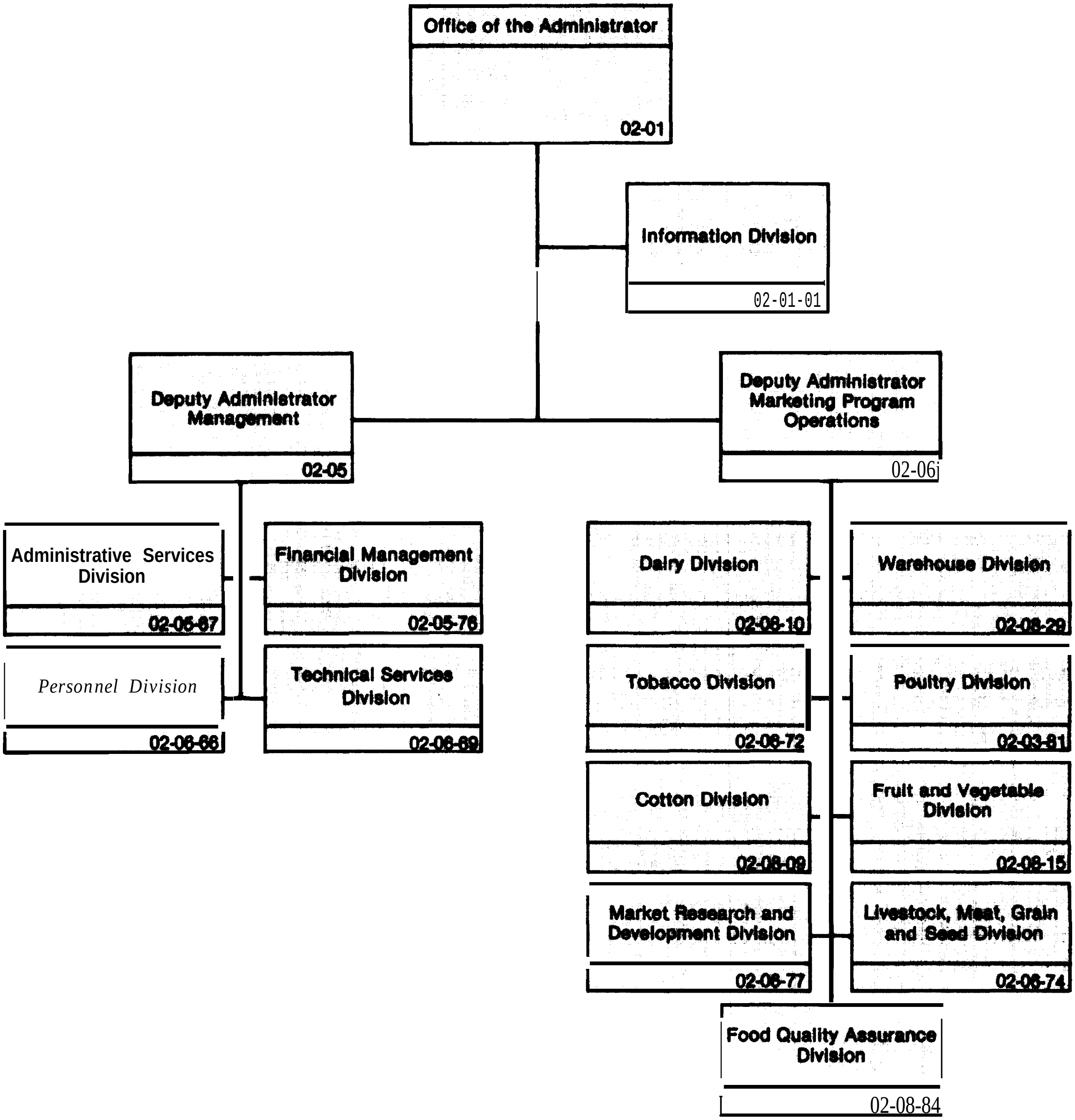
AMS marketing research is conducted by the Marketing Research Branch of the Market Research and Development Division (see figs. 31 and 32). The Marketing Research Branch has three groups: 1) the animal products group, 2) the food distribution facilities group, and 3) the marketing system group. The animal products group conducts studies of marketing facilities and methods used in the assembly, processing, and distribution of meat animal, dairy, and poultry products. The food distribution facilities group is oriented toward analyzing needs and providing technical assistance for improvements in wholesale food marketing facilities in metropolitan areas and, similarly, for assembly market facilities for fruits, vegetables, and other crops, The marketing systems group conducts research on methods of receipt, storage, loading, shipping, packaging, palletizing, inventory control, delivery wholesaling, and retailing of agricultural products. Emphasis is placed on analysis of new or alternative methods of handling food products under existing or proposed operating conditions, such as firm size and location, to improve the efficiency of marketing.

The research activities of the marketing research branch of AMS represent only one aspect of PHTME research, the physical handling of products at the wholesale level in the marketing chain. Although many AMS marketing research activities would benefit from an interdisciplinary approach, the present organization of USDA is not conducive to interdisciplinary research efforts. Other research that would complement and support AMS research is scattered among other USDA agencies, primarily ARS and ERS, and in many ARS field locations. Little coordination exists between AMS and the other agencies involved in this research (6).

Another concern is the placement of a research division in an action agency such as AMS. Historically, such placement has not provided a favorable environment for research. It usually results in: 1) administrators who are inexperienced and unfamiliar with research and problems unique to research organizations and, thus, less sensitive to their needs; 2) research directed to short-term applied problems at the expense of equally important, longer term basic research; 3) research tending to be less respected by scientific peers because the agency is oriented to action and less concerned with research; and 4) research that can easily be politicized so that research goals and directions shift with each change in administration (1). The above concerns have some validity. The administration's 1983 and 1984 budget proposal recommended the AMS research program be discontinued.

Serious consideration should be given to consolidating the present research functions of AMS with other major PHTME research efforts. As noted earlier, over 95 percent of the AMS budget is for providing market news and implementing regulatory activities. It seems that if there is a research component to this agency, the research it conducts might more appropriately be focused on the agency's major mission. This would include, for example, research to evaluate the benefits and costs of regulations proposed by AMS and the effect of such regulations on the postharvest and marketing sector and other sectors of the U.S. economy. Research on the effects of AMS regulations would provide AMS with an information base that it could use to improve, modify, or eliminate regulations to the benefit of society. ERS states that a part of its mission is to conduct this research for action agencies such as AMS. However, little ERS research is conducted in this area (8).

Figure31 .—Organization of the Agriculturai Marketing Servce

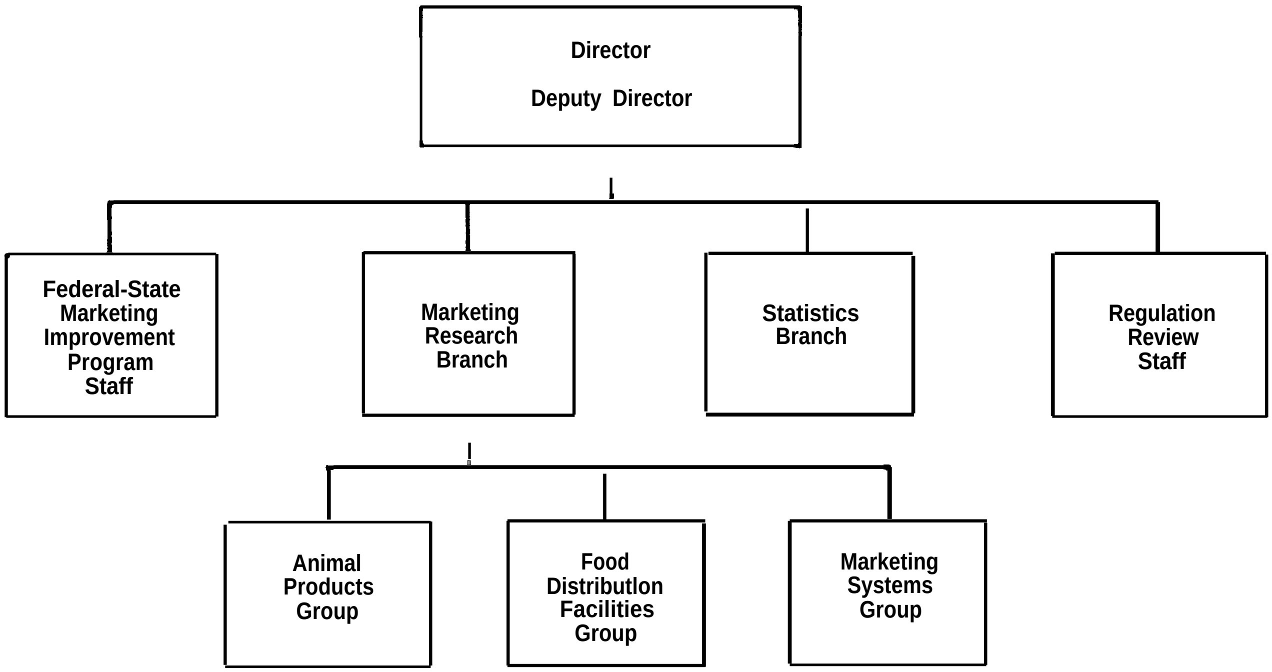


The mission of the Agricultural Marketing Service is to provide marketing services such as grading and inspection, market news, marketing agreements and orders, and related programs for various agricultural commodities, including cotton, milk, fruits and vegetables, grain, livestock, poultry, tobacco and related products to administer a program designed to license and bond public warehouseman storing agricultural products and weighers and samplers of such products; and to administer a said regulatory program.

Supersedes AMS Chart dated July 9, 1979.

SOURCE: U.S. Department of Agriculture, Agricultural Marketing Service, 1982.

Figure 32.—Organization of the Market Research and Development Division of AMS



SOURCE: U S. Department of Agriculture, Agriculture Marketing Service, 1982.

COOPERATIVE STATE RESEARCH SERVICE*

CSRS is responsible for administering Federal funds that go to States for PHTME and all other agricultural research. Traditionally CSRS has developed a close working relationship with SAES, the schools of forestry, and the 1890 Colleges and Tuskegee Institute. Many of the staff were former scientists at these universities. The Administrator is a member of the Experiment Station Committee on Organization and Policy and meets regularly with it on research matters of interest to the States and USDA.

In coordinating research among the States and between the States and USDA, CSRS staff represent the States. This representation involves budgets, research priorities, formula v. grant funds, coordination, and in fact most problems the SAES have.

*This is an abbreviated discussion of CSRS that pertains to PHTME Research. For a more detailed discussion, see ref. 4.

Reviews of Research

Desk Reviews

All research proposals to be financed in whole or in part from Hatch Act funds are reviewed by CSRS scientific staff. By mutual consent between CSRS and the SAES directors, all State-supported projects are also sent to CSRS. Thus, the CSRS staff is knowledgeable of all activities at the State level. To review the hundreds of projects in the PHTME research area, however, there were only two food scientists and one marketing economist on the CSRS staff in 1982.

The CSRS desk project review process sometimes is not productive. Most SAES directors submit good outlines; some do not. Some CSRS staff members make excellent contributions to the outline; others do not (2). Under the present administration, attempts are being made to have this function performed at the State level.

Onsite Reviews

CSRS also conducts onsite reviews of research programs in progress. Onsite reviews are conducted as part of CSRS' responsibility for coordinating research sponsored by Hatch Actor grant funds, but by mutual consent between CSRS and SAES directors these reviews extend to all SAES research, regardless of the source of funds.

The purpose of CSRS onsite reviews is to serve the needs of the institution or group that requested the review. Onsite reviews are conducted every 3 to 5 years and generally cover broad subject areas such as food science and agricultural economics research. Such reviews legally are not required, but most SAES personnel believe they are beneficial (2). If no request is forthcoming for a review of an area of work within 3 to 4 years, CSRS may suggest that a review be undertaken.

Onsite review teams include experts from universities, USDA, and the private sector. At the close of their review, these teams give an oral and written report to the scientists, department head, and the SAES director. Acceptance of recommendations concerning programs for the future—onsite reviews deal only briefly with the past—is an option that is left with the client institution.

Administration of Grants

CSRS also administers a research grants program that uses the competitive process in the selection of grantees. These programs are:

1. competitive research grants program to support basic research in the food and agricultural sciences,
2. special research grants program to support research deemed by Congress and USDA to be of particular importance to the Nation,
3. alcohols and industrial hydrocarbons program, and
4. native latex research program.

A concern raised in the OTA report An Assess*ment of the United States Food and Agricultural Research System* was whether CSRS was the appropriate agency to administer the Competitive Research Grants program. All U.S. research institutions and scientists that have expertise and capabilities are supposed to be (and should be) considered equally as possible grantees. Having CSRS, whose main function and purpose is so closely tied to the SAES (which receives a large share of the grants), administer these grants gave reason for concern.

A conclusion from the OTA report was that the Competitive Grants program be removed from CSRS and possibly placed under the direct control of the Assistant Secretary for Science and Education. The present administration has placed the program under the Assistant Secretary for Science and Education, but for budgetary purposes the program remains with CSRS.

Regional Research

The Hatch Act provides that up to 25 percent of the funds may be used for regional research to "stimulate and facilitate interstate cooperation on research of a regional and national character both among SAES and the United States Department of Agriculture" (5). Much of PHTME research has been supported by these funds.

The regional projects carried out under the SAES basically involve a group of scientists from different SAES working on a problem of importance to more than one State. The funds for regional projects which CSRS allocates give these scientists an opportunity to get together and exchange information and to coordinate their efforts. Generally, however, there is no one who is charged with responsibility of allocating resources (personnel and funds) to any given area of activity, there is no one who is held accountable, and there is no assurance that all aspects of the needed research will be covered. * Nevertheless, these regional funds have been extremely useful. Not only do they benefit the work that is important to each of the cooperating States, but they usually result in a greater and more coordinated effort than there would have been without such funds.

● One exception to this is NC117, a regional project in PHTME research on the Organization and Performance of the U.S. Food Production and Distribution System. It has a full-time executive director with authority to allocate resources and who is accountable. It is a model other regional research projects could emulate.

CONCLUSIONS

Currently, public sector PHTME research is fragmented among and within several Federal agencies and SAES. ARS, ERS, and AMS each reports to a different Assistant Secretary within USDA: ARS reports to the Assistant Secretary of Science and Education; ERS reports to the Assistant Secretary for Economics; and AMS reports to the Assistant Secretary for Marketing and Transportation Services. This situation makes it difficult to coordinate public PHTME research efforts, so that problems of national or regional importance are adequately and efficiently addressed.

Through all the numerous USDA organizational changes described in appendix D, PHTME research has been combined with, separated from, and recombined with production and other kinds of research. The frequency of change within the past decade has made it difficult to sustain an effective PHTME research program in the public sector.

PRINCIPAL FINDINGS

- PHTME research is scattered throughout USDA. Most of the research is conducted in three separate agencies-ARS, ERS, and AMS. The fact that each of these agencies reports to a different Assistant Secretary inhibits the coordination of the public PHTME research efforts.
- ARS conducts most of USDA's postharvest technology research. Since 1972, ARS has been organized along regional lines, with ARS regional offices in regions corresponding to the SAES regions. While this arrangement is conducive to interdisciplinary research efforts, the boundaries of ARS regions bear little or no relationship to postharvest technology research problems, because such problems generally do not follow State lines. Furthermore, the reassignment of national program investigation leaders to national program staff positions in ARS with no line authority has diminished the national perspective and national technical leadership in the agency's postharvest technology research efforts.
- ERS conducts most of USDA's marketing economics research. Since 1973, marketing economics research has been fragmented within ERS and has not been an organizationally identifiable research activity. This arrangement has resulted in a loss of financial support for marketing economics research and has impeded cooperation with ARS laboratories and university departments of agricultural economics.
- AMS is primarily an action agency that provides market news services and implements regulatory activities, such as grading and inspection. AMS research activities represent only one aspect of PHTME research-namely, the physical handling of products at the wholesale level in the marketing chain. Little coordination exists between AMS and agencies involved in other related PHTME research. Furthermore, the placement of a research division in an action agency such as AMS does not provide a favorable environment for research.
- CSRS is responsible for administering Federal funds that go to States for PHTME and other agricultural research. CSRS desk reviews of research proposals have been less than in-depth examinations, and acceptance of recommendations from onsite reviews of research in progress is an option left to the client institution.
- SAES and the land-grant universities are organized by disciplinary areas, and this organization may inhibit interdisciplinary PHTME research activities involving food scientists and agricultural economists.

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Appendixes

Appendix A

Research Problem Areas in Postharvest Technology and Marketing Economics Research

The particular research problem areas (RPAs) included in postharvest technology and marketing economics (PHTME) research are presented in table A-1. Most of the RPAs dealing with PHTME research are contained in research goals IV, V, VI, and VII. * None of the RPAs in goals I, II, and VIII were judged to contain any PHTME research. In some RPAs, all of the research is concerned with PHTME, while for other RPAs, only part of the research is really PHTME-oriented. For the latter RPAs, information is not available to allocate the proportions of the total expenditure for the RPA to PHTME and to the other types of research. Thus, the criterion adopted was that if any part or all of the research in a particular RPA was concerned with PHTME problems, the entire expenditure for that RPA was considered in PHTME. This criterion will lead to an overstatement of the amount of funds allocated to PHTME in some RPAs. The alternative criterion, which was to exclude RPAs that were not totally concerned with PHTME, would result in an understatement of the funds allocated to PHTME research.

*The research goals evolved from the long-range study of agricultural research published by USDA in 1966, under the title, "A National Program of Research for Agriculture "

Table A-1.– Research Problem Areas (RPAs) Involved in PHTME Research

Goal 1: Ensure a stable and productive agriculture for the future through wise management of natural resources
(No RPAs)

Goal 11: Protect forests, crops, and livestock from insects, disease, and other hazards
(No RPAs)

Goal Ill: Produce an adequate supply of farm and forest products at decreasing real production costs
- 316 Farm Business Management

Goal IV: Expand the demand for farm and forest products by developing new and improved products and processes and enhancing product quality
- 403 New and Improved Fruit and Vegetable Products and By-products
- 404 Quality Maintenance in Storing and Marketing Fruits and Vegetables
- 406 New and Improved Food Products from Field Crops
- 407 New and Improved Feed, Textile, and Industrial Products from Field Crops
- 408 Quality Maintenance in Storing and Marketing Field Crops
- 410 New and Improved Meat, Milk, Eggs, and Other Animal Food Products
- 411 New and Improved Nonfood Animal Products
- 412 Quality Maintenance in Marketing Animal Products

Goal V: Improve efficiency in the marketing system
- 501 Improvement of Grades and Standards—Crop and Animal Products
- 503[a] Efficiency in Marketing Agricultural Products and Production Inputs
- 506 Supply, Demand, and Price Analysis—Crop and Animal Products
- 507 Competitive Interrelationships in Agriculture
- 508 Development of Domestic Markets for Farm Products
- 509 Performance of Marketing Systems
- 510 Group Action and Market Power
- 511 Improvement in Agricultural Statistics

Goal Vl: Expand export markets and assist developing nations
- 601 Foreign Market Development
- 604 Product Development and Marketing for Foreign Markets

Goal Vll: Protect consumer health and improve nutrition and well-being of the American people
- 701 Insure Food Products Free of Toxic Residues from Agricultural Sources
- 702 Protect Food and Feed Supplies from Harmful Micro-organisms and Naturally Occurring Toxins
- 703 Food Choices, Habits, and Consumption
- 704 Home and Commercial Food Service
- 707 Prevent Transmission of Animal Diseases and Parasites to Man
- 708 Human Nutrition

Goal Vlll: Assist Rural Americans to improve their level of living
(No RPAs)

Goal IX: Promote community improvement including development of beauty, recreation, environment, economic opportunity, and public services
- 901 Alleviation of Soil, Water, and Air Pollution and Disposal of Wastes

[a]This RPA Incorporates research formerly included under RPAs 503,504, and 505

SOURCE Office of Technology Assessment

Appendix B

Postharvest Technology and Marketing Economics Research Expenditures for Selected Commodities

This appendix focuses on comparisons of postharvest technology and marketing economics (PHTME) and total research expenditures by the State agricultural experiment stations (SAES) and the U.S. Department of Agriculture (USDA) for selected commodities in order to obtain some insight into the patterns of expenditures on PHTME research for various commodities. The commodities considered were selected on a judgment basis and included selected vegetables, field crops, and livestock.

Potatoes

The current dollar expenditures by SAES and USDA on PHTME and total research on potatoes during the 1966-81 period are presented in figure B-1 and the constant dollar expenditures are presented in figure B-2. * In both SAES and USDA, the current dollar expenditures on total research on potatoes increased during the 1966-81 period, with an overall increase of **267** percent in SAES and 154 percent in USDA. In constant dollars, the increase in SAES was **25** percent, while for USDA the constant dollar expenditures decreased 13 percent over the 16-year period.

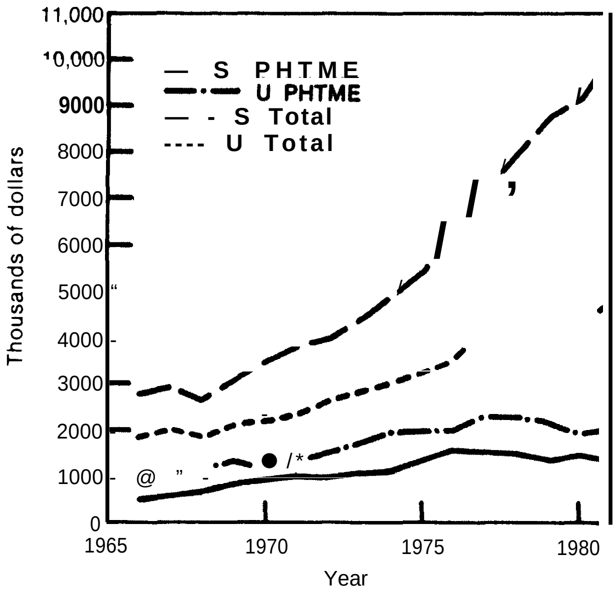
Current dollar expenditures on PHTME research on potatoes varied in both SAES and USDA during the 1966-81 period, and decreased from 1977 to 1980 in both SAES and USDA. In constant dollars, the expenditures from **1966 to 1981** decreased by **5** percent in SAES and decreased by **23** percent in USDA. The percent of total research expenditures for potatoes devoted to PHTME research varied in SAES from about **27** percent in **1969 to 1971 to 14** percent in **1981, and** in USDA from about **63** percent in **1969 to 42** percent in 1981.

● Data used to construct these and all remaining figures in this appendix can be found in app. C.

Other Vegetables

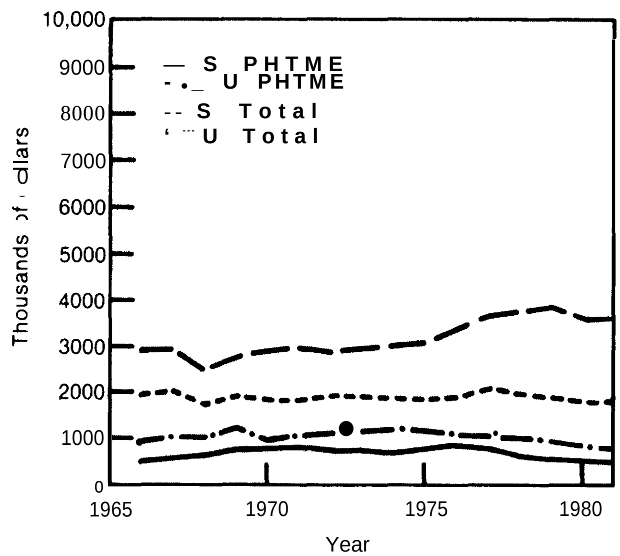
The USDA and SAES current dollar expenditures during the 1966-81 period on PHTME and total re-

Figure B-1.— Potato PHTME and Total Research ‘Expenditures by SAES and USDA, 1966-81 (in current dollars)



SOURCE Office of Technology Assessment

Figure B-2.— Potato PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in constant dollars)



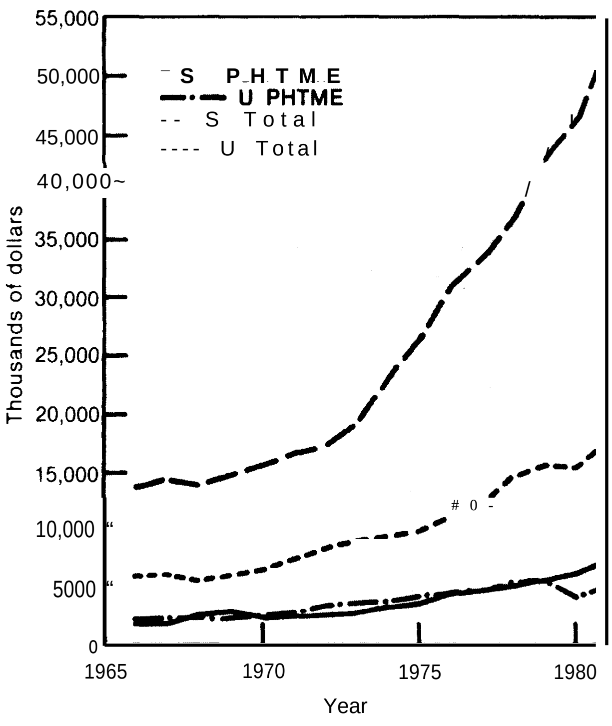
SOURCE Off Ice of Technology Assessment

search on vegetables other than potatoes are presented in figure B-3, and the corresponding constant dollar expenditures are shown in figure B-4. The total funds allocated to all other vegetable research were substantially greater in SAES than in USDA and increased at a more rapid rate in the SAES. In current dollar expenditures, the overall increase from 1966 to 1981 was 284 percent in SAES and 202 percent in USDA. The corresponding changes in constant dollar expenditures were a 31-percent increase in SAES and a 3-percent increase in USDA.

In SAES, PHTME research expenditures as a percent of total research expenditures on vegetables other than potatoes reached a peak of 19 percent in 1969 and decreased to about 14 percent in 1981. From 1966 to 1981, the current dollar expenditures on PHTME research on vegetables other than potatoes increased 305 percent, while the increase in constant dollars was only 38 percent.

In USDA, the current dollar expenditures on PHTME research on vegetables other than potatoes increased 167 percent from 1966 to 1981, and the constant dollar expenditures decreased 9 percent. PHTME research expenditures as a percent of total research expenditures on vegetables other than potatoes ranged from a high of 42 percent in 1975 to a low of 29 percent in 1980, and were 30 percent in 1981.

Figure B-3.—Other Vegetables, PHTME AND Total Research Expenditures by SAES and USDA, 1966-81 (in current dollars)



SOURCE Office of Technology Assessment

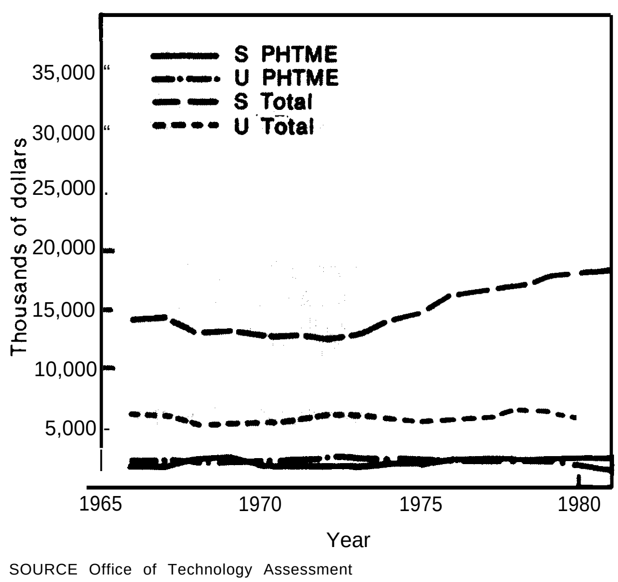
Corn

Current and constant expenditures on PHTME and total research on corn by the SAES and USDA for the 1966-81 period are presented in figures B-5 and B-6, respectively. The current dollar expenditures on total corn research increased 377 percent from 1966 to 1981 in the SAES and 115 percent in USDA. In SAES, constant dollar expenditures increased 58 percent, but in USDA the constant dollar expenditures decreased by 27 percent. Also, the expenditures on total corn research during the 16-year period fluctuated more in USDA than in SAES.

The current dollar expenditures on corn PHTME research from 1966 to 1981 increased 603 percent in SAES, while the constant dollar expenditures increased 140 percent. With some minor fluctuation, the increases were steady throughout the 16-year period. USDA current dollar expenditures on corn PHTME research exhibited a similar pattern, but the overall increase from 1966 to 1981 was 30 percent and constant dollar expenditures declined 56 percent.

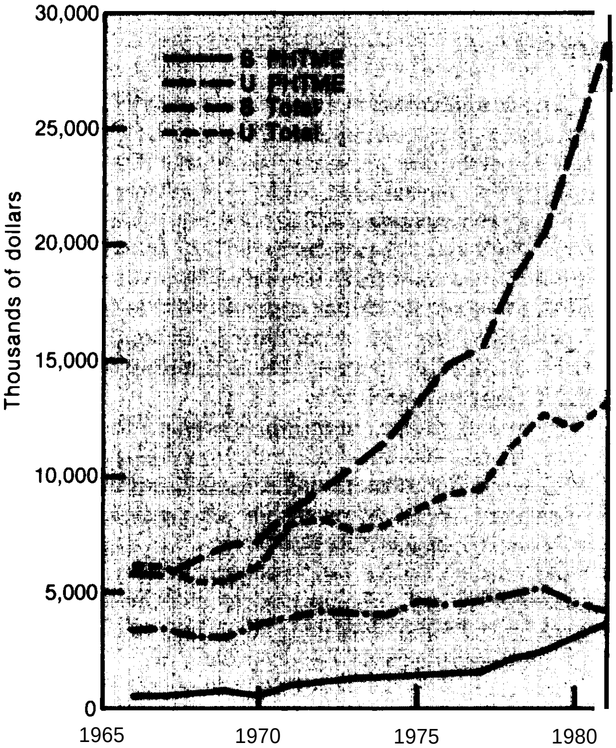
Expenditures in SAES on PHTME research as a percent of expenditures on all corn research ranged from a low of 8 percent in 1970 to a high of 13 percent in

Figure B-4.—Other Vegetables, PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in constant dollars)



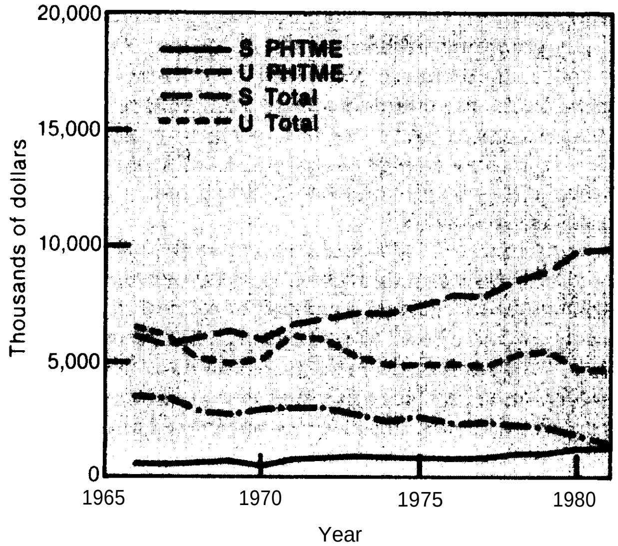
SOURCE Office of Technology Assessment

Figure B-5.—Corn PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in current dollars)



SOURCE: Off Ice of Technology Assessment.

Figure B-6.—Corn PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in constant dollars)



SOURCE: Office of Technology Assessment.

1973 and 1981. The USDA corresponding percentage ranged from a high of 59 percent in 1970 to a low of 32 percent in 1981.

Wheat

Current and constant dollar expenditures on PHTME and total research on wheat by the SAES and USDA for the 1966-81 period are presented in figures B-7 and B-8, respectively, SAES current dollar expenditures on wheat research increased much more rapidly than did total USDA expenditures, and by 1975 exceeded those of USDA. In current dollar expenditures, the overall increase from 1966 to 1981 was 408 percent in SAES and only 83 percent in USDA. In constant dollars, the SAES increase was 74 percent, and the USDA expenditures decreased by 38 percent. In 1981, the SAES expenditure on wheat research was 55 percent greater than that of USDA.

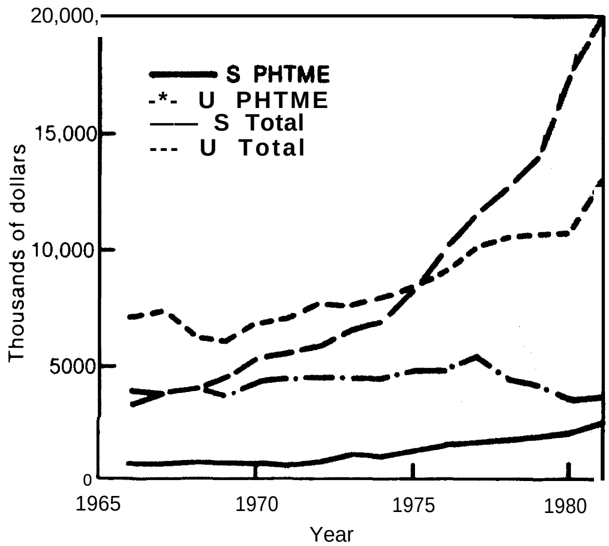
Current dollar expenditures on wheat PHTME research for the 1966-81 period increased 220 percent in the SAES system and 10 percent in USDA. In constant dollars, these increases translate into a 9-percent increase in the SAES and a 62-percent decrease in USDA. As a percent of total expenditures on wheat research, expenditures on wheat PHTME research in the SAES ranged from a high of 22 percent in 1968 to a low of 12 percent in 1981. The USDA low was 28 percent in 1981, and the high was 65 percent in 1970.

Soybeans

Current and constant dollar expenditures on PHTME and total research on soybeans by the SAES and USDA for the 1966-81 period are presented in figures B-9 and B-10, respectively. Current dollar expenditures of the SAES on all soybean research increased by 1,205 percent from 1966 to 1981, and in USDA increased by 454 percent. In constant dollars, the increase in SAES was 346 percent and in USDA, 89 percent.

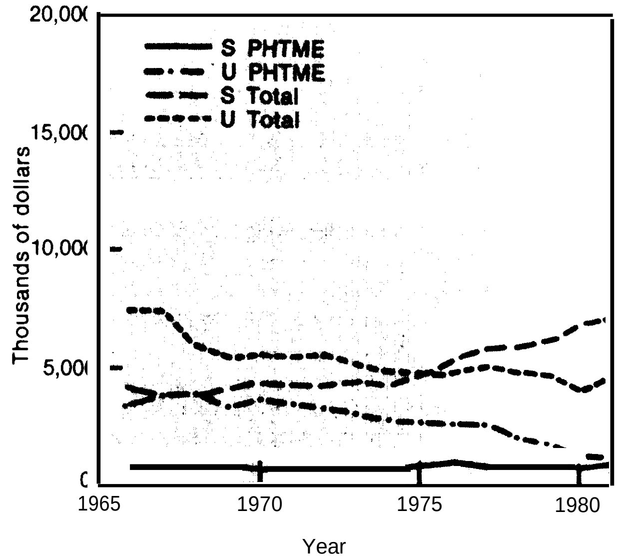
Current dollar expenditures on soybean PHTME research for the 1966-81 period increased over thirteenfold in SAES, and in constant dollars the increase was 390 percent. In USDA, the increase from 1966 to 1981 in current dollars was 223 percent, but in constant dollars this increase was only 10 percent. USDA expenditures on soybean PHTME research steadily decreased in constant dollars from 1978 to 1981. In SAES, expenditures on soybean PHTME research as a percent of total expenditures on all soybean research ranged from a high of 10 percent in 1968 to a low of 7 per-

Figure B-7.—Wheat PHTME and Total Research Expenditures by SAES and USDA, 1966-81
(in current dollars)



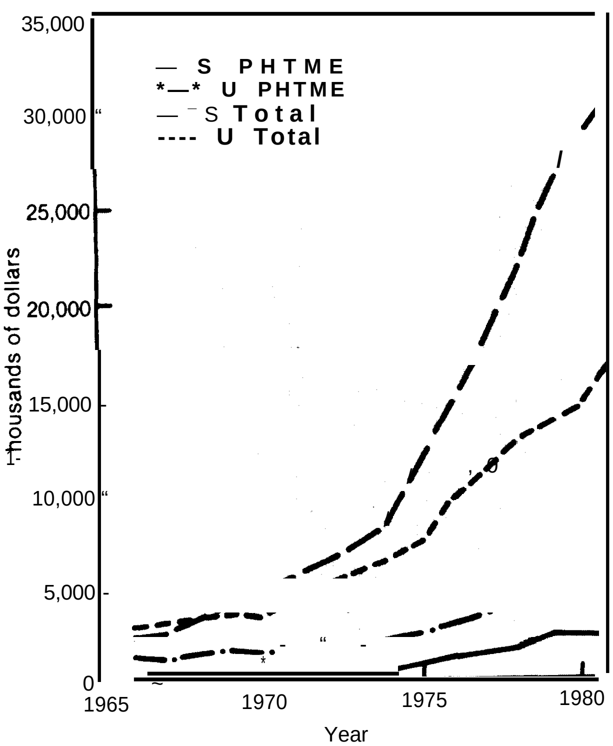
SOURCE Office of Technology Assessment

Figure B-8.—Wheat PHTME and Total Research Expenditures by SAES and USDA, 1966-81
(in constant dollars)



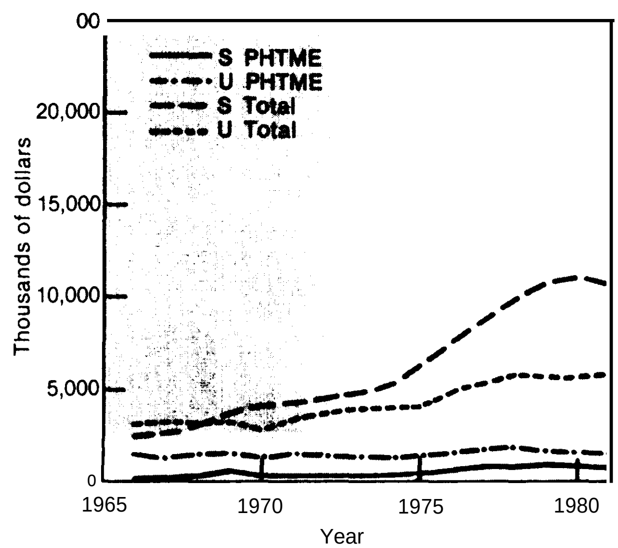
SOURCE: Office of Technology Assessment.

Figure B-9.—Soybean PHTME and Total Research Expenditures by SAES and USDA, 1966-81
(in current dollars)



SOURCE Office of Technology Assessment

Figure B-10.—Soybean PHTME and Total Research Expenditures by SAES and USDA, 1966-81
(in constant dollars)



SOURCE Off Ice of Technology Assessment

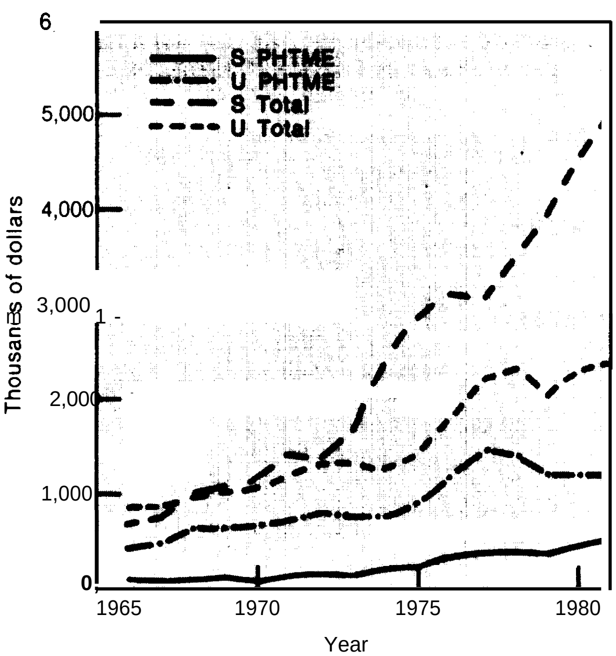
cent in 1981. In USDA, expenditures on soybean PHTME as a percent of total expenditures on all soybean research ranged from a high of 46 percent in 1969 to a low of 26 percent in 1981.

Rice

Current and constant dollar expenditures on PHTME and on total research on rice by the SAES and USDA for the 1966-81 period are presented in figures B-II and B-12, respectively. Current dollar expenditures in the SAES on **all** rice research increased by 667 percent and in USDA by 185 percent. In constant dollars, the overall increase for the 16-year period was 162 percent in the SAES, while the constant dollar expenditures in USDA decreased 2 percent. From 1977 to 1981, both current and constant dollar expenditures on total rice research increased in the SAES.

Current dollar expenditures on rice PHTME research for the 1966-81 period increased about 463 percent in the SAES, while constant dollar expenditures increased 94 percent. In USDA, the increase from 1966 to 1981 was 185 percent in current dollar expenditures and a decrease of 3 percent in constant dollar expenditures. The decrease in USDA expenditures occurred during the last 4 years of the 16-year period. In the SAES,

Figure B-n .—Rice PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in current dollars)



SOURCE Office of Technology Assessment,

expenditures on rice PHTME research as a percent of total expenditures on all rice research ranged from a high of 13 percent in 1966 to a low of 7 percent in **1970,** and the proportion for 1981 was 10 percent. In USDA, expenditures on rice PHTME research **as a** proportion of total expenditures on all rice research ranged from a high of **67** percent in 1977 to a low of **51** percent in 1966 and 1981.

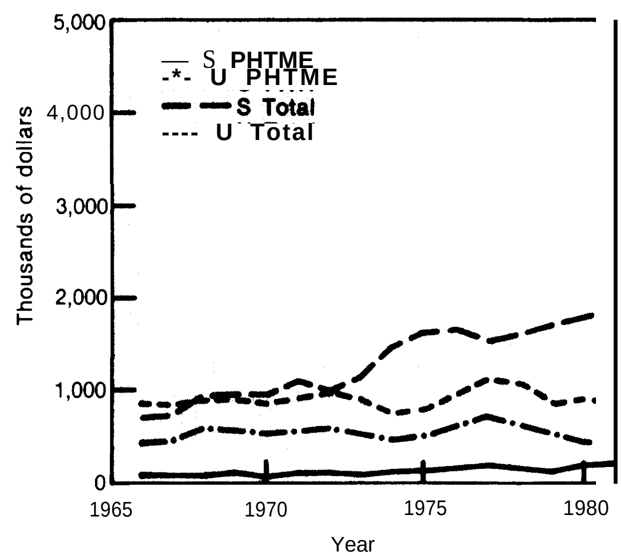
Cotton

The SAES and USDA PHTME and total research expenditures on cotton for the 1966-81 period in current and constant dollars are presented in figures B-13 and B-14, respectively. For all commodities discussed thus far, the total SAES expenditure in current dollars exceeded that of USDA. However, this is not true for cotton, The total USDA expenditures on cotton research were approximately **65** percent greater than those of the SAES.

The expenditures by USDA on cotton research increased 131 percent in current dollars from **1966** to 1981, but the constant dollar expenditures decreased by **21** percent. In the SAES, the current dollar expenditures increased by **148** percent from **1966** to **1981,** while the constant dollar expenditures decreased by 15 percent.

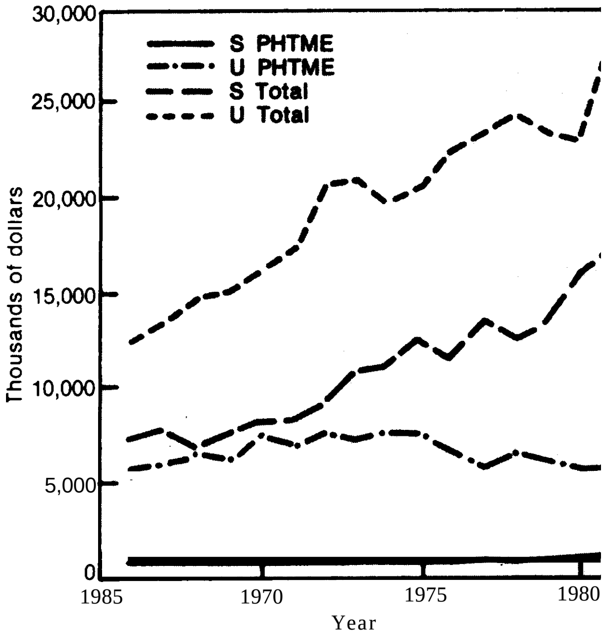
USDA current dollar expenditures on cotton PHTME research varied considerably over the 1966-81 period, and increased only 2 percent. The corresponding con-

Figure B-12.— Rice PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in constant dollars)



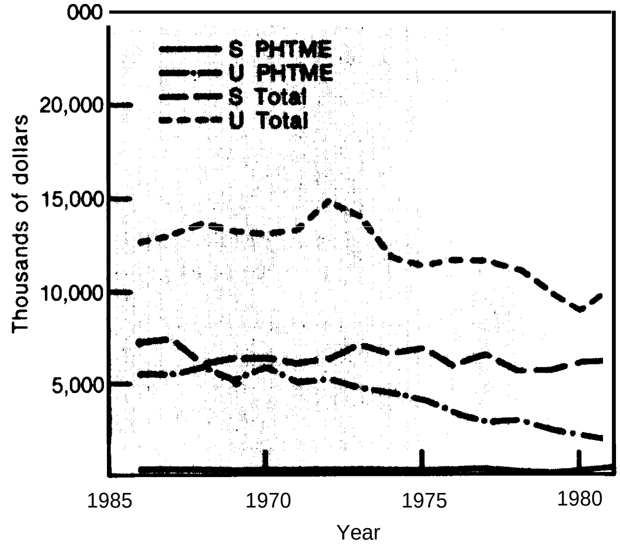
SOURCE: Office of Technology Assessment.

Figure B-13.—Cotton PHTME and Total Research Expenditures by SAES and USDA, 1966-81
(in current dollars)



SOURCE" Off Ice of Technology Assessment.

Figure B-14.—Cotton PHTME and Total Research Expenditures by SAES and USDA, 1966-81
(In constant dollars)



SOURCE: Office of Technology Assessment.

stant dollar expenditure declined by 65 percent. In the SAES, the increase in current dollars on cotton PHTME research for the same period was 150 percent, while the corresponding constant dollar expenditure declined 14 percent, USDA expenditures on cotton PHTME research relative to total expenditures on cotton research ranged from a high of 44 percent in **1970 to a low of 19** percent in 1981. In the SAES, the corresponding proportions ranged from a high of **5** percent in 1968 and 1981 to a low of 3 percent in 1979.

Dairy

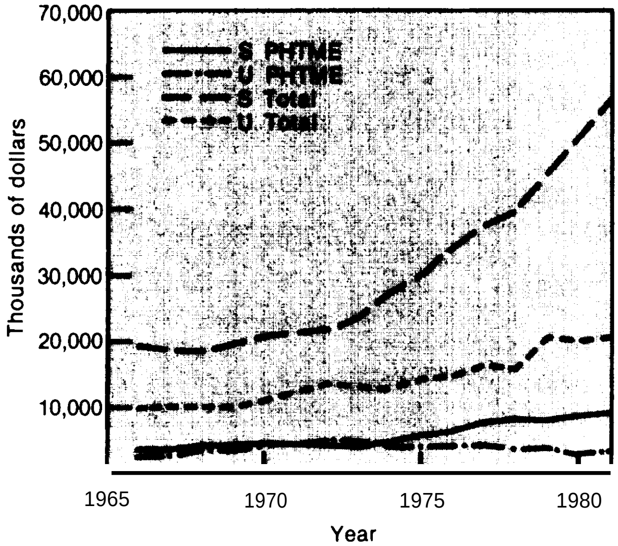
Current and constant dollar expenditures by the SAES and USDA on PHTME and all dairy research for the 1966-81 period are presented in figures B-15 and B-16, respectively. Current dollar expenditures on all dairy research in the SAES increased 193 percent from 1966 to 1981, while the constant dollar expenditures remained level. The current dollar expenditures in USDA increased by 116 percent, but the constant dollar expenditures for the same 16-year period declined 26 percent. The total expenditures in the SAES on all dairy research during the **1966-81** period were from **74** percent to approximately 165 percent greater than the expenditures in USDA.

Current dollar expenditures in the SAES on dairy PHTME research, which includes marketing research, increased **170** percent from 1966 to 1981, but corresponding constant dollar expenditures declined 8 percent, For the same period, the current dollar expenditures on dairy PHTME research in USDA increased 21 percent, while constant dollar expenditures declined 59 percent. In the SAES, expenditures on dairy PHTME research as a percent of expenditures on all dairy research ranged from a high of 22 percent in 1970 to a low of 17 percent in **1973 and 1981.** In USDA, the comparable percentages for the 16-year period ranged from a high of **37** percent in 1972 to a low of **13** percent in 1981,

Beef

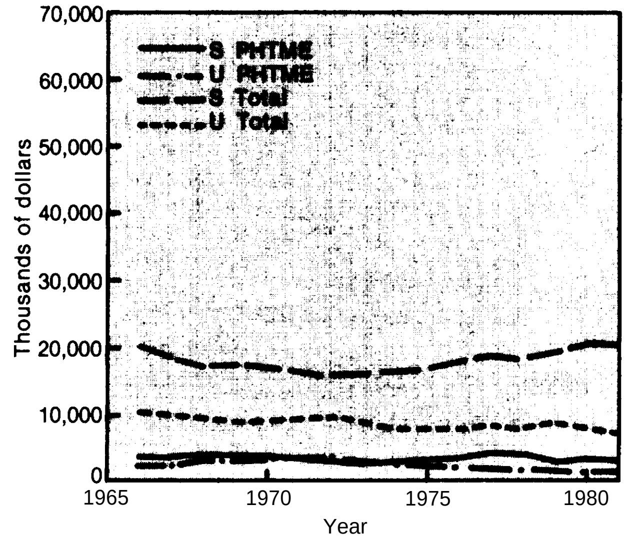
Current and constant dollar expenditures by the SAES and USDA on PHTME and all beef research for the 1966-81 period are presented in figures B-17 and B-18, respectively. Current dollar expenditures for all beef research in the SAES increased 333 percent from 1966 to 1981, and constant dollar expenditures increased **48** percent. The current dollar expenditures in USDA increased 213 percent, but the constant dollar expenditures increased only 7 percent. In **a** pattern similar to that of dairy research, total expenditures in the SAES on all beef research during the **1966-81** period were from **63** percent to **145** percent greater than the expenditures in USDA.

Figure B-15.—Dairy PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in current dollars)



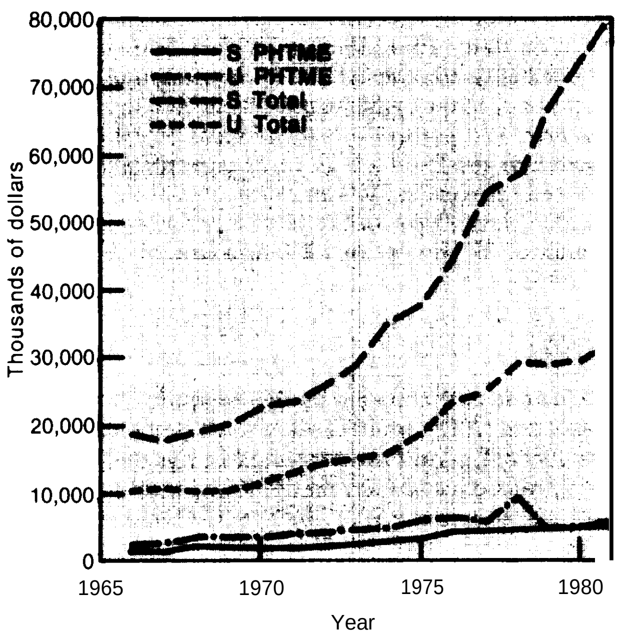
SOURCE: Office of Technology Assessment.

Figure B-16.—Dairy PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in constant dollars)



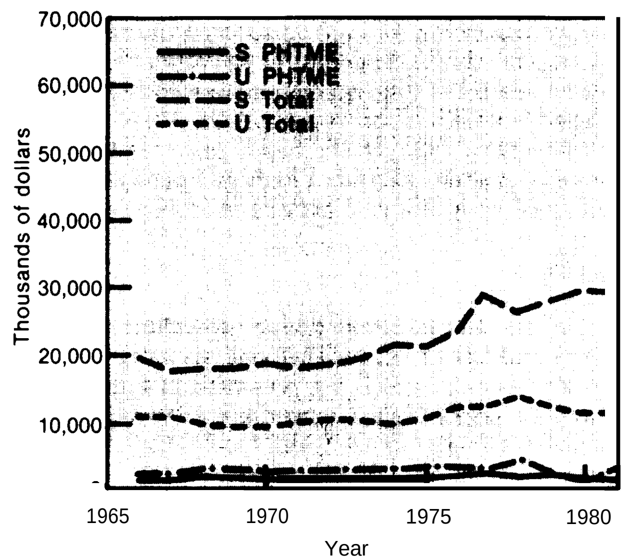
SOURCE: Office of Technology Assessment.

Figure B-17.—Beef PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in current dollars)



SOURCE: Office of Technology Assessment.

Figure B-18.—Beef PHTME and Total Research Expenditures by SAES and USDA, 1966-81 (in constant dollars)



SOURCE: Office of Technology Assessment.

Current dollar expenditures in the SAES on beef PHTME research increased 265 percent from 1966 to 1981, while the corresponding constant dollar expenditures increased 25 percent. During the same 16-year period, the current dollar expenditures on beef PHTME research in USDA increased 142 percent, but constant dollar expenditures declined 18 percent. SAES expenditures on beef PHTME research as a percent of expenditures on all beef research ranged from a high of 12 percent in 1968 to a low of 6 percent in 1981. In USDA, the comparable percentages for the 1966-81 period ranged from a high of 33 percent in 1969 to a low of 17 percent in 1980. The 1981 proportion for USDA was about 18 percent.

Appendix C
Statistics on Agricultural Research Expenditures*

Table C-1 .—Combined SAES and USDA Research Expenditures on PHTME, Production, Other, and Totai Agricuiturai Research in Current and Constant Doiiars, 1966-81 (thousands of dollars)

Year	Total research expenditure		PHTME research expenditure		Production research expenditure		Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$ 358,300	$375,971	$87,187	$91,487	$237,706	$249,429	$33,406	$35,054
1967	373,100	373,100	91,991	91,991	243,012	243,012	38,096	38,096
1968	401,840	380,891	94,274	89,359	267,026	253,105	40,537	38,424
1969	423,160	378,159	99,183	88,883	276,815	247,377	47,159	42,144
1970	459,000	379,339	104,909	86,702	304,591	251,728	49,498	40,907
1971	497,310	384,023	116,753	90,157	323,257	249,619	57,298	44,246
1972	571,250	414,249	133,751	96,991	367,757	266,684	69,742	50,574
1973	614,950	417,765	143,791	97,684	394,389	267,927	76,769	52,153
1974	670,790	416,578	154,973	96,498	429,987	267,725	85,852	53,457
1975	755,120	429,289	165,978	94,359	493,299	280,443	95,842	54,487
1976	830,130	443,446	180,966	96,670	542,818	289,987	106,344	56,808
1977	949,310	475,371	198,470	99,384	619,699	310,315	131,147	65,672
1978	1,043,185	485,654	215,553	100,351	680,888	316,987	146,743	68,316
1979	1,139,419	491,341	228,510	98,538	754,490	325,351	156,420	67,451
1980	1,246,355	490,112	236,844	93,136	848,977	333,849	160,534	63,128
1981a	1,399,578	501,282	259,574	92,971	964,685	345.518	175,319	62,793

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, Inventory *of Agricultural Research FY 1966-81, Vo;. II.*

Table C-2.—USDA Expenditures on PHTME, Production, Other, and Total Agricultural Research in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	USDA Total research expenditure		USDA PHTME research expenditure		USDA Production research expenditure		USDA Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$153,084	$160,634	$54,306	$58,985	$87,887	$92,221	$10,891	$11,428
1987	165,424	165,424	57,783	57,783	94,945	94,945	12,696	12,696
1968	159,150	150,853	56,273	53,339	91,197	86,443	11,680	11,071
1969	163,865	146,439	57,634	51,505	93,691	83,727	12,540	11,207
1970	176,896	146,195	62,268	51,461	100,578	83,122	14,051	11,612
1971	197,084	152,188	70,642	54,550	109,052	84,210	17,390	13,428
1972	224,308	162,680	79,196	57,430	124,093	89,988	21,019	15,242
1973	236,291	160,524	82,339	55,936	131,078	89,047	22,874	15,540
1974	240,183	149,554	86,683	53,974	132,826	82,706	20,674	12,873
1975	265,604	150,997	93,786	53,318	144,936	82,397	25,804	14,669
1976	302,531	161,608	100,618	53,749	173,632	92,752	29,235	15,617
1977	343,859	172,188	107,653	53,907	202,235	101,269	33,971	17,011
1978	380,557	177,168	117,892	54,885	228,838	106,535	33,826	15,748
1979	391,738	168,925	117,261	50,565	241,694	104,223	32,784	14,137
1980	417,305	164,099	116,665	45,877	263,824	103,745	36,816	14,477
1981[a]	483,246	173,082	132,244	47,365	308,173	110,377	42,829	15,340

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, Inventory *of Agricultural Research* FY *1966-81, Vol. II.*

● **Many of the current and constant total dollar figures will not be the same as those found in the OTA report An Assessment of** *the United States Food and Agricultural Research System.* This is because of revisions made by USDA to current dollar figures and the changes In the deflator made by the U.S. Department of Commerce.

Table C-3.—SAES Expenditures on PHTME, Production, Other, and Total Agricultural Research in Current and Constant Dollars, 1966-81 (thousands of dollars)

	SAES Total research expenditure		SAES PHTME research expenditure		SAES Production research expenditure		SAES Other research expenditure	
Year	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	**$205,215**	$215,336	$32,881	$34,503	$149,819	$157,208	$22,515	**$23,625**
1967	**207,675**	207,675	34,208	34,208	148,067	148,067	25,400	**25,400**
1968	**242,687**	230,035	38,001	36,020	175,829	166,663	28,857	**27,353**
1969	**259,292**	231,718	41,549	37,130	183,124	163,650	34,619	**30,937**
1970	**282,101**	233,141	42,641	35,240	204,013	168,606	35,447	**29,295**
1971 ....., ...	**300,224**	231,833	46,111	35,607	214,205	165,409	39,908	**30,817**
1972	**346,942**	251,590	54,555	39,561	243,664	176,696	48,723	**35,332**
1973	**378,658**	257,240	61,452	41,747	263,311	178,880	53,895	**36,613**
1974	**430,609**	268,125	68,290	42,522	297,141	185,019	65,178	**40,584**
1975	**490,054**	278,598	72,192	41,042	347,824	197,740	70,038	**39,817**
1976	**527,120**	281,581	80,348	42,921	369,663	197,470	77,109	**41,191**
1977.	**605,455**	303,182	90,817	45,477	417,464	209,046	97,176	**48,661**
1978.	**662,628**	308,486	97,661	45,466	452,050	210,452	112,917	**52,568**
1979.	**747,681**	322,415	111,249	47,973	512,796	221,128	123,636	**53,314**
1980.	**829,050**	326,013	120,179	47,259	570,486	224,336	138,385	**54,418**
1981a	**916,332**	328,199	127,330	45.605	585,153	230,103	123,718	**48,650**

[a]Preliminary.

SOURCE: Compiled from the U.S Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81 Vol II.*

Table C-4.—SAES Expenditures on PHTME and on Total Agricultural Research as a Percent of Combined USDA/SAES Expenditures on PHTME and Total Agricultural Research, 1966-81* (percentage)

Year	Total SAES research	PHTME SAES research
1966.	0.573	0.377
1967.	0.557	0.372
1968.	0.604	0.403
1969.	0.613	0.419
1970.	0.615	0.406
1971	0.604	0.395
1972.	0.607	0.408
1973.	0.616	0.427
1974.	0.642	0.441
1975.	0.649	0.435
1976.	0.635	0.444
1977.	0.638	0.458
1978.	0.635	0.453
1979.	0.656	0.487
1980.	0.666	0.507
1981[b].	0.655	0.491

[a]SAES is SAES and other cooperating institutions.
[b]Preliminary,

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81 Vol. II.*

Table C-5.—Private Industry Funds for Applied Research and Development of Agricultural Chemicals, Farm Machinery, and Food and Kindred Products in Current and Constant Dollars, 1963-75 (millions of dollars)

	Food and kindred		Farm machinery		Agricultural chemicals		Total private agricultural research	
Year	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1963	102	118	76	88	45	52	223	258
1964	118	133	79	89	48	54	245	277
1965	131	144	96	105	64	70	291	320
1966	130	136	100	105	77	81	307	322
1967	134	134	102	102	92	92	328	328
1968	165	156	96	91	99	94	360	341
1969	179	160	99	88	104	93	382	341
1970	204	169	89	74	126	104	419	346
1971	207	160	90	69	130	100	427	330
1972	222	161	92	67	108	78	422	306
1973	234	159	117	79	114	77	465	316
1974	269	167	127	79	137	85	533	332
1975	292	166	145	82	165	94	602	342

SOURCE National Science Foundation, "Table E-51 Research and Development In Industry 1975," Surveys of Science *Resources Series,* NSF77-324, p 72.

Table C-6.—Agricultural Research Service (ARS) Expenditures on Total PHTME, Production, and Other Agricultural Research uncurrent and Constant Dollars, 1966-81 (thousands of doilars)

	ARS Total research expenditure		ARS PHTME research expenditure		ARS Production research expenditure		ARS Other research expenditure	
Year	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$136,761	$143,506	$46,211	$48,491	$85,214	$ 89,416	$ 5,336	$5,599
1967	145,716	145,716	49,356	49,356	90,055	90,055	6,305	6,305
1968	142,405	134,981	46,331	43,916	88,642	84,021	7,432	7,045
1969	146,801	131,189	47,570	42,511	91,181	81,484	8,050	7,194
1970	161,113	133,151	53,560	44,264	98,828	81,676	8,725	7,211
1971	176,076	135,966	59,240	45,745	106,396	82,159	10,440	8,062
1972	192,617	139,679	63,315	45,914	117,850	85,460	11,452	8,305
1973	200,322	136,088	66,310	45,048	122,354	83,121	11,658	7,920
1974	206,995	128,889	69,010	42,970	124,831	77,728	13,154	8,190
1975	224,096	127,400	72,335	41,123	137,235	78,019	14,526	8,258
1976	252,514	134,890	76,734	40,990	159,503	85,205	16,278	8,696
1977	292,956	146,698	84,070	42,098	190,045	95,165	18,841	9,435
1978	323,147	150,440	90,685	42,218	212,373	98,870	20,089	9,352
1979	338,032	145,766	91,615	39,506	227,363	98,044	19,054	8,216
1980	360,347	141,702	95,225	37,446	243,291	95,671	21,831	8,585
1981=	419,356	150,199	107,825	38,619	285,774	102,355	25,757	9,225

‘Preliminary.

SOURCE: Compiled from the U.S Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY l966-81, Vol, II,*

Table C-7.—Economic Research Service (ERS) Expenditures on Total, PHTME, Production, and Other Agricultural Research in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	ERS Total research expenditure		ERS PHTME research expenditure		ERS Production research expenditure		ERS Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$16,323	$17,128	$ 8,095	$8,494	$ 2,673	$2,805	$5,555	$5,829
1967	17,711	17,711	8,427	8,427	2,893	2,894	6,391	6,391
1968	14,775	14,005	9,832	9,319	865	820	4,078	3,865
1969	15,064	13,462	9,950	8,592	737	659	4,378	3,912
1970	14,089	11,644	8,567	7,080	336	278	5,187	4,287
1971	18,361	14,178	11,227	8,669	324	250	6,810	5,259
1972	19,191	13,916	12,213	8,856	361	262	6,617	4,798
1973	20,569	13,974	12,354	8,393	973	661	7,242	4,920
1974	21,605	13,453	13,366	8,323	3,087	1,922	5,152	3,208
1975	24,497	13,927	15,757	8,958	1,535	873	7,205	4,096
1976	28,520	15,235	17,097	9,133	2,223	1,188	9,201	4,915
1977	29,000	14,522	17,051	8,538	1,920	962	10,029	5,021
1978	33,702	15,690	20,296	9,449	4,661	2,170	8,745	4,071
1979	37,141	16,016	22,392	9,656	2,755	1,188	11,993	5,172
1980	42,626	16,762	18,229	7,168	10,673	4,197	13,723	5,396
1981a	46,546	16,671	21,354	7,648	9,486	3,398	15,706	5,625

aPreliminary

SOURCE Compiled from the US Department of Agriculture, Science and Education Administration, *Inventort of Agricultural Research FY 1966-81 Vol* II

Table C-8.—Marketing Research Expenditures by Agricultural Marketing Service, 1947-81 (thousands occurrent dollars)

Year	Thousands of dollars
1947-53	Unable to determine conclusively
1954	3,884
1955	5,105
1956	5,652
1957	6,446
1958	7,197
1959	7,460
1960	7,211
1961	4,214
1982	4,306
1963	4,787
1964	2,915 (part year)
1965-78	O
1979	1,237
1980	1,277
1981	1,418

SOURCE: Agricultural Marketing Service, 1982

Table C-9.—SAES Expenditures from Hatch Act Funds on Total, PHTME, Production, and Other Agricultural Research in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	Hatch Total research expenditure		Hatch PHTME research expenditure		Hatch Production research expenditure		Hatch Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$48,017	**$50,385**	**$10,877**	$11,413	$31,287	**$32,830**	**$5,853**	$6,142
1967	48,694	**48,694**	**11,286**	11,286	30,882	**30,882**	**6,526**	6,526
1968	52,449	**49,715**	**11,505**	10,905	34,418	**32,624**	**6,526**	6,186
1969	53,912	**48,179**	**11,877**	10,614	34,459	**30,794**	**7,576**	6,770
1970	56,439	**46,644**	**12,420**	10,264	36,042	**29,787**	**7,977**	6,593
1971	62,743	**48,450**	**14,124**	10,907	38,117	**29,434**	**10,502**	8,110
1972	70,587	**51,187**	**16,465**	11,940	41,440	**30,051**	**12,682**	9,197
1973	77,220	**52,459**	**18,940**	12,867	44,126	**29,977**	**14,154**	9,615
1974	82,127	**51,138**	**20,284**	12,630	45,975	**28,627**	**15,868**	9,880
1975	90,302	**51,337**	**20,802**	11,826	52,173	**29,661**	**17,327**	9,850
1976	102,505	**54,757**	**24,810**	13,253	57,020	**30,459**	**20,675**	11,044
1977	116,761	**58,468**	**28,216**	14,129	66,347	**33,223**	**22,198**	11,116
1978	132,179	**61,536**	**28,793**	13,405	79,226	**36,884**	**24,160**	11,248
1979	154,033	**66,422**	**31,307**	13,500	94,699	**40,836**	**28,027**	12,086
1980	160,416	**63,081**	**31,273**	12,298	101,189	**39,791**	**27,954**	10,993
1981a	171,803	**61,534**	**30,617**	10,966	111,183	**39,822**	**30,003**	10,746

[a]Preliminay.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81 Vol II.*

Table C-10.—SAES Expenditures From Cooperative Grants and Cooperative Agreements (CGCA) Funds for Total, PHTME, Production, and Other Research in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	CGCA Total research expenditure		CGCA PHTME research expenditure		CGCA Production research expenditure		CGCA Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$6,008	$6,304	$1,559	$1,636	$3,926	$4,120	$ 523	$ 549
1967	6,260	6,260	1,707	1,707	4,004	4,004	549	549
1968	9,594	9,094	1,835	1,739	6,850	6,493	909	862
1969	7,784	6,956	1,611	1,440	5,310	4,745	863	771
1970	6,837	5,650	1,467	1,212	4,727	3,907	643	531
1971	6,320	4,880	1,170	903	4,495	3,471	655	506
1972	6,850	4,967	1,548	1,123	4,548	3,298	754	547
1973	7,476	5,079	1,527	1,037	4,721	3,207	1,228	834
1974	8,631	5,374	1,639	1,021	5,364	3,340	1,628	1,014
1975	10,773	6,125	1,814	1,031	6,827	3,881	2,132	1,212
1976	9,882	5,279	1,423	760	6,998	3,738	1,461	780
1977	11,758	5,888	1,912	957	7,138	3,574	2,708	1,356
1978	14,783	6,882	2,541	1,183	8,705	4,053	3,537	1,647
1979	19,141	8,254	3,156	1,361	11,282	4,865	4,703	2,028
1980	24,362	9,580	3,833	1,507	14,984	5,892	5,545	2,180
1981[a]	**29,821**	**10,681**	**5,479**	**1,962**	**18,872**	**6,759**	**5,470**	**1,959**

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, Inventory of *Agricultural Research FY 1966-81, Vol. II.*

Table C-11 .—SAES Expenditures From Other Federal Sources for PHTME, Production, Other, and Total Agricultural Research in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	OTH Federal Total research expenditure		OTH Federal PHTME research expenditure		OTH Federal Production research expenditure		OTH Federal Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	**$24,522**	$25,731	$5,050	**$5,299**	$16,584	$17,402	**$2,888**	$3,030
1967	**23,566**	23,566	5,158	**5,158**	15,517	15,517	**2,891**	2,891
1968	**28,602**	27,111	6,561	**6,219**	18,900	17,915	**3,141**	2,977
1969	**27,834**	24,874	6,785	**6,063**	16,545	14,786	**4,504**	4,025
1970	**26,440**	21,851	5,782	**4,779**	17,613	14,556	**3,045**	2,517
1971	**25,957**	20,044	6,581	**5,082**	16,514	12,752	**2,862**	2,210
1972 .., ...	**27,299**	19,796	6,243	**4,527**	17,462	12,663	**3,594**	2,606
1973	**28,748**	19,530	6,739	**4,578**	18,680	12,690	**3,329**	2,262
1974	**31,205**	19,430	6,117	**3,809**	20,010	12,460	**5,078**	3,162
1975	**34,236**	19,463	6,573	**3,737**	23,153	13,163	**4,510**	2,564
1976	**37,772**	20,177	7,744	**4,137**	24,952	13,329	**5,076**	2,712
1977	**51,760**	25,919	10,741	**5,379**	34,234	17,143	**6,785**	3,398
1978	**53,590**	24,949	9,967	**4,640**	33,782	15,727	**9,841**	4,581
1979.	**60,967**	26,290	13,398	**5,777**	37,539	16,188	**10,030**	4,325
1980.	**67,622**	26,591	13,187	**5,186**	44,299	17,420	**10,136**	3,986
1981a	**77,911**	27,905	12,793	**4,582**	53,892	19,280	**11,258**	4,032

[a]Preliminary.

SOURCE: Compiled from the U.S Department of Agriculture, Science and Education Administration, *Inventory of Agricultural* Research FY 1966-81, *Vol* II

Table C-12.—SAES Expenditures From State Appropriations on Total, PHTME, Production, and Other Agricultural Research in Current and Constant Dollars, 1966.81 (thousands of dollars)

Year	State Total research expenditure		State PHTME research expenditure		State Production research expenditure		State Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$117,942	$123,759	$14,022	$14,714	$91,751	$96,276	$12,169	$12,769
1967	120,610	120,610	14,573	14,573	91,667	91,667	14,370	14,370
1968	142,276	134,859	16,428	15,572	109,628	103,913	16,220	15,374
1969	157,526	140,774	19,018	16,996	118,610	105,996	19,898	17,782
1970	178,666	147,658	20,512	16,952	136,491	112,802	21,663	17,803
1971 .., ...	190,892	147,407	22,057	17,032	145,126	112,066	23,709	18,308
1972	226,185	164,021	27,825	20,178	169,339	122,798	29,021	21,045
1973	247,691	168,268	31,127	21,146	184,132	125,090	32,432	22,033
1974	288,022	179,341	36,471	22,709	212,300	132,192	39,251	24,440
1975	331,270	188,329	39,031	22,189	250,655	142,499	41,584	23,641
1976	349,502	186,700	42,086	22,482	261,459	139,668	45,957	24,550
1977	393,359	196,975	45,344	22,706	288,371	144,402	59,644	29,867
1978	428,489	199,483	51,307	23,886	308,001	143,390	69,181	32,207
1979	477,787	206,031	57,913	24,973	345,447	148,964	74,427	32,094
1980	530,524	208,621	65,738	25,851	390,941	153,732	73,845	29,039
1981 [a].	585,822	209,822	70,722	25,330	437,225	156,599	77,875	27,892

[a]Preliminary.

SOURCE: Compiled from the US Department of Agriculture, Science and Education Administration, Inventory of Agricultural Research *FY 1966-81, Vol. II.*

Table C-13.—SAES Expenditures From Private Industry Funds on Total, PHTME, Production, and Other Agricultural Research in Current and Constant Dollars, 1966=81 (thousands of dollars)

Year	Private Total research expenditure		Private PHTME research expenditure		Private Production research expenditure		Private Other research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$8,726	$9,156	$1,373	$1,441	$6,271	$6,580	$1,082	$1,135
1967	8,545	8,545	1,484	1,484	5,997	5,997	1,064	1,064
1968	9,766	9,257	1,672	1,585	6,033	5,718	2,061	1,954
1989	12,236	10,935	2,258	2,018	8,200	7,328	1,778	1,589
1970	13,719	11,338	2,460	2,033	9,140	7,554	2,119	1,751
1971	14,312	11,052	2,179	1,683	9,953	7,686	2,180	1,683
1972	16,021	11,618	2,474	1,794	10,875	7,886	2,672	1,938
1973	17,523	11,904	3,119	2,119	11,652	7,916	2,752	1,870
1974	20,624	12,842	3,779	2,353	13,492	8,401	3,353	2,088
1975	23,473	13,345	3,972	2,258	15,016	8,537	4,485	2,550
1976	27,459	14,668	4,285	2,289	19,234	10,275	3,940	2,105
1977	31,819	15,933	4,604	2,305	21,374	10,703	5,841	2,925
1978	33,587	15,636	5,053	2,352	22,336	10,399	6,198	2,885
1979	35,753	15,417	5,475	2,361	23,829	10,276	6,449	2,781
1980	46,126	18,138	6,148	2,418	33,740	13,268	6,238	2,453
1981a	50,975	18,258	7,719	2,765	35,372	12,669	7,884	2,824

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81 Vol II.*

Table C-14.–Potatoe PHTME and Total Agricultural Research Expenditures by SAES and USDA in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1986	$ 488	$512	$2,758	$2,894	$ 880	$ 923	$1,838	$1,929
1967	575	575	2,924	2,924	1,022	1,022	2,007	2,007
1968	653	619	2,630	2,493	1,068	1,012	1,839	1,743
1969	833	744	3,053	2,728	1,333	1,191	2,103	1,879
1970	936	773	3,466	2,864	1,149	950	2,177	1,799
1971	1,027	793	3,808	2,941	1,342	1,036	2,332	1,801
1972	980	711	3,941	2,858	1,482	1,075	2,617	1,898
1973	1,069	726	4,334	2,944	1,693	1,150	2,777	1,887
1974	1,092	680	4,862	3,027	1,928	1,200	2,999	1,867
1975	1,359	773	5,398	3,069	1,943	1,105	3,222	1,832
1976	1,554	830	6,319	3,376	1,967	1,050	3,497	1,868
1977	1,610	806	7,197	3,603	2,288	1,146	4,222	2,114
1978	1,477	688	8,002	3,725	2,286	1,064	4,201	1,956
1979	1,362	587	8,765	3,780	2,146	925	4,242	1,829
1980	1,464	576	9,189	3,613	1,896	746	4,205	1,654
1981[a]	1,367	489	10,131	3,629	1,978	709	4,668	1,672

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81, Vol. II.*

Table C-15.—Other Vegetables PHTME and Total Agricultural Research Expenditures by SAES and USDA in Current and Constant Dollars, 1966-81 (thousands of dollars)

	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
Year	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$1,839	$1,930	$13,660	$14,334	2,001	**$2,099**	$5,911	$6,203
1967	1,863	1,863	14,401	14,401	2,143	**2,143**	6,072	6,072
1968	2,513	2,382	13,933	13,207	2,196	**2,082**	5,561	5,271
1969	2,875	2,569	14,815	13,240	2,393	**2,139**	6,014	5,374
1970	2,430	2,008	15,590	12,884	2,549	**2,107**	6,531	5,398
1971	2,515	1,942	16,669	12,872	2,848	**2,200**	7,388	5,705
1972	2,564	1,859	17,317	12,558	3,474	**2,519**	8,492	6,158
1973	2,728	1,853	19,067	12,953	3,623	**2,461**	9,090	6,175
1974	3,357	2,090	23,125	14,399	3,777	**2,352**	9,503	5,917
1975	3,670	2,085	26,295	14,949	4,190	**2,382**	9,925	5,642
1976	4,555	2,433	30,818	16,463	4,597	**2,456**	11,116	5,938
1977 ....., ...	4,959	2,483	33,530	16,790	4,942	**2,474**	12,280	6,149
1978	5,314	2,474	37,093	17,269	5,493	**2,557**	14,713	6,850
1979	5,765	2,486	42,453	18,307	5,311	**2,290**	15,820	6,821
1980.	6,352	2,498	46,740	18,380	4,411	**1,735**	15,400	6,056
1981a	7,444	2,666	52,425	18,777	5,340	**1,913**	17,837	6.389

[a]Preliminary,

SOURCE Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81, Vol.* II.

Table C-16.—Corn PHTME and Total Agricultural Research Expenditures by SAES and USDA in Current and Constant Dollars, 1966-81 (thousands of dollars)

	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
Year	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$ 532	$ 558	$5,783	$6,068	$3,330	$3,494	$6,164	$6,468
1967	531	531	5,690	5,690	3,415	3,415	6,100	6,100
1968	664	630	6,332	6,002	3,054	2,895	5,433	5,150
1969	736	658	6,975	6,233	3,044	2,720	5,457	4,877
1970 ....., ...	557	460	7,153	5,912	3,600	2,975	6,106	5,046
1971	1,014	783	8,477	6,546	3,930	3,248	7,911	6,109
1972	1,165	845	9,455	6,856	4,162	3,018	8,166	5,922
1973	1,350	917	10,424	7,082	4,036	2,742	7,645	5,194
1974	1,369	852	11,492	7,156	3,973	2,474	7,888	4,912
1975	1,450	824	13,071	7,431	4,568	2,597	8,590	4,883
1976	1,457	778	14,794	7,903	4,371	2,335	9,187	4,908
1977	1,546	774	15,578	7,801	4,679	2,343	9,608	4,811
1978	2,247	1,046	18,411	8,571	4,936	2,298	11,434	5,323
1979	2,452	1,057	20,673	8,915	5,299	2,285	12,815	5,526
1980	3,193	1,256	24,697	9,712	4,535	1,783	12,322	4,845
1981a	3,739	1,339	27,595	9,884	4,311	1,544	13,270	4,753

[a]Preliminary

SOURCE" Compiled from the U.S. Department of Agriculture, Science and Education Administration, Inventory *of Agricultural Research FY 1966-81, Vol* I.

Table C-17.–Wheat PHTME and Total Agricuiturai Research Expenditures by SAES and USDA in Current and Constant Doiiars, 1966-81 (thousands of dollars)

Year	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$ 774	$812	$3,928	$4,122	$3,344	$3,509	$ 7,077	$7,426
1967	731	731	3,826	3,826	3,825	3,825	7,376	7,376
1968	862	817	3,999	3,791	4,115	3,900	6,313	5,984
1969	870	777	4,547	4,063	3,797	3,393	6,083	5,436
1970	868	717	5,266	4,352	4,385	3,624	6,777	5,601
1971	712	550	5,526	4,267	4,492	3,469	7,077	5,465
1972	893	647	5,889	4,270	4,530	3,285	7,645	5,544
1973	1,213	824	6,524	4,432	4,451	3,024	7,584	5,152
1974	1,145	713	6,904	4,299	4,491	2,797	7,945	4,947
1975	1,408	800	8,186	4,654	4,825	2,743	8,434	4,795
1976.	1,650	882	9,925	5,302	4,883	2,608	9,099	4,861
1977.	1,734	868	11,601	5,809	5,400	2,704	10,106	5,061
1978.	1,871	871	12,717	5,920	4,483	2,087	10,709	4,986
1979.	2,025	873	14,130	6,093	4,292	1,851	10,813	4,663
1980.	2,156	847	17,536	6,896	3,652	1,436	10,868	4,274
Lila.	2,475	886	19,970	7,153	3,684	1,319	12,923	4,629

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81 Vol,* II

Table C-18.–Soybean PHTME and Total Agricultural Research Expenditures by SAES and USDA in Current and Constant Dollars, 1966.81 (thousands of dollars)

Year	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966.	$ 155	$162	$2,340	$2,455	$1,346	$1,413	$2,986	$3,133
1967.	171	171	2,572	2,572	1,258	1,258	3,227	3,227
1968.	335	317	3,217	3,049	1,478	1,401	3,366	3,190
1969.	672	600	4,200	3,753	1,682	1,503	3,636	3,249
1970.	408	337	4,976	4,112	1,524	1,260	3,379	2,793
1971	488	376	5,491	4,240	1,922	1,484	4,373	3,377
1972.	435	315	6,309	4,575	1,950	1,414	5,144	3,730
1973.	502	341	7,118	4,836	1,987	1,350	5,786	3,931
1974.	601	374	8,570	5,336	2,156	1,342	6,579	4,097
1975.	909	516	11,312	6,431	2,465	1,401	7,331	4,168
1976.	1,246	666	14,515	7,754	2,978	1,591	9,329	4,983
1977.	1,655	829	17,913	8,970	3,502	1,753	10,877	5,447
1978.	1,827	851	21,550	10,033	3,939	1,834	12,650	5,889
1979.	2,273	980	25,367	10,939	3,931	1,695	13,484	5,815
1980.	2,391	940	28,398	11,167	4,228	1,663	14,579	5,733
1981a	2,213	793	30,541	10,939	4,346	1,556	16,533	5,922

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agricultural Science and Education Administration, *Inventory of Agricultural Research FY 1966-81, Vol.* I.

Table C-19.– Rice PHTME and Total Agricultural Research Expenditures by SAES and USDA in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$90	$ 94	$ 673	$ 706	$ 420	$440	$ 823	$863
1967	86	86	728	728	462	462	838	838
1968	86	82	987	936	621	589	956	906
1969	120	107	1,067	954	629	562	1,019	911
1970	77	64	1,138	940	646	534	1,049	867
1971	128	99	1,407	1,086	701	548	1,187	917
1972	154	111	1,363	988	822	596	1,341	972
1973	142	96	1,660	1,127	771	524	1,336	908
1974	212	132	2,374	1,478	773	481	1,233	768
1975	236	134	2,881	1,638	905	515	1,410	802
1976	333	178	3,114	1,663	1,167	623	1,794	958
1977	367	184	3,069	1,537	1,466	734	2,205	1,104
1978	374	174	3,469	1,615	1,423	662	2,332	1,086
1979	362	156	3,966	1,710	1,210	522	2,019	871
1980	454	179	4,554	1,791	1,199	471	2,298	904
1981[a]	507	182	5,161	1,848	1,196	429	2,369	848

[a]Preliminary

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81 Vol* I.

Table C-20.—Cotton PHTME and Total Agricultural Research Expenditures by SAES and USDA in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$337	$353	$6,895	$7,235	$5,252	$5,510	$12,102	$12,698
1967	373	373	7,414	7,414	5,485	5,485	13,062	13,062
1968	349	330	6,406	6,072	6,222	5,897	14,427	13,675
1969	373	333	7,137	6,378	5,830	5,210	14,780	13,208
1970	381	315	7,745	6,401	7,037	5,816	15,825	13,079
1971	353	273	7,899	6,100	6,581	5,082	17,184	13,269
1972	389	282	8,701	6,310	7,210	5,229	20,377	14,777
1973	481	327	10,407	7,070	6,938	4,714	20,658	14,034
1974	432	269	10,753	6,696	7,270	4,527	19,357	12,053
1975	393	224	12,211	6,942	7,200	4,093	20,193	11,480
1976	449	240	11,115	5,938	6,365	3,400	22,014	11,760
1977	477	239	13,175	6,597	5,491	2,750	23,099	11,567
1978	440	205	12,071	5,620	6,276	2,922	24,082	11,211
1979	458	198	12,947	5,583	5,838	2,517	23,099	9,961
1980	575	226	15,337	6,031	5,371	2,112	22,676	8,917
1981[a]	842	302	17,100	6,125	5,377	1,936	27,997	10,028

[a]Preliminary

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81, Vol.* I.

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Table C-21 .–Dairy PHTME and Total Agricultural Research Expenditures by SAES and USDA in Current and Constant Dollars, 1966-81 (thousands of dollars)

Year	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$3,487	$3,659	$19,324	$20,277	$2,352	$2,468	$9,869	$10,356
1967	3,503	3,503	18,607	18,607	2,471	2,471	10,162	10,162
1968	4,030	3,819	18,463	17,500	3,493	3,311	10,048	9,524
1969	4,160	3,718	19,541	17,463	3,440	3,074	10,022	8,956
1970	4,491	3,711	20,686	17,096	3,973	3,283	11,014	9,102
1971	4,328	3,342	21,190	16,363	4,386	3,387	12,295	9,494
1972	4,292	3,112	21,824	15,826	5,075	3,680	13,640	9,891
1973	3,914	2,659	23,566	16,010	4,735	3,217	13,176	8,951
1974	4,632	2,854	27,074	16,858	3,869	2,409	12,794	7,966
1975	5,775	3,283	29,748	16,912	3,929	2,234	14,245	8,098
1976	6,378	3,407	34,068	18,199	3,869	2,067	14,726	7,866
1977	7,323	3,667	37,362	18,709	3,808	1,907	17,567	8,797
1978	7,738	3,602	39,708	18,486	2,978	1,386	16,338	7,606
1979	7,644	3,296	45,428	19,589	3,344	1,442	21,608	9,318
1980	8,834	3,474	51,670	20,319	2,540	999	19,992	7,862
1981a	9,402	3,368	56,677	20,300	2,846	1,019	21,361	7,651

[a]Preliminary.

SOURCE: Compiled from the US. Department of Agriculture, Science and Education Administration, Inventory of Agrlcultural *Research FY 1966-81, Vol. I.*

Table C-22.–Beef PHTME and Total Agricultural Research Expenditures by SAES and USDA uncurrent and Constant Dollars, 1966.81 (thousands of dollars)

Year	SAES PHTME research expenditure		SAES Total research expenditure		USDA PHTME research expenditure		USDA Total research expenditure	
	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars	Current dollars	Constant dollars
1966	$1,438	$1,508	$18,677	$19,598	$2,408	$2,527	$10,445	$10,960
1967	1,484	1,484	17,729	17,729	2,491	2,491	10,862	10,882
1968	2,216	2,100	19,050	18,057	3,330	3,157	10,316	9,778
1969	2,094	1,872	20,121	17,981	3,427	3,063	10,460	9,348
1970	1,902	1,572	22,637	18,708	3,388	2,800	11,338	9,370
1971	1,883	1,454	23,385	18,058	3,888	3,002	13,078	10,099
1972	2,306	1,672	25,739	18,665	4,062	2,945	14,416	10,454
1973	2,402	1,632	28,872	19,614	4,739	3,220	15,163	10,301
1974	2,918	1,817	34,978	21,780	4,892	3,046	15,922	9,914
1975	3,247	1,846	37,596	21,374	5,971	3,395	18,751	10,660
1976	4,266	2,279	44,178	23,599	6,307	3,369	23,212	12,400
1977	4,348	2,177	55,179	27,631	5,751	2,880	24,131	12,084
1978	4,504	2,097	57,557	26,796	9,163	4,249	29,818	13,882
1979	4,999	2,156	66,594	28,717	5,152	2,222	28,631	12,346
1980	5,244	2,062	75,363	29,635	5,056	1,988	29,525	11,610
1981a	5,243	1,878	80,864	28,963	5,822	2,085	32,669	11,701

[a]Preliminary.

SOURCE: Compiled from the U.S. Department of Agriculture, Science and Education Administration, *Inventory of Agricultural Research FY 1966-81 Vol* I.

Appendix D

Development of Public Postharvest Technology and Marketing Economics Research*

Early agricultural societies created considerable interest in agricultural experimentation in the first half of the 1800's. Independently and nearer the middle of the century, a number of American scientists who received graduate training in Europe brought back the idea of agricultural experiment stations. This concept was presented to the agricultural societies and other such groups. But little resulted in formal terms except for some institutionalization of fertilizer analyses.

Two major steps toward creation of agricultural research systems were taken in 1862, when: 1) the President signed a bill on May 15 establishing the U.S. Department of Agriculture (USDA), and 2) Congress passed the Merrill Act on July 2, which provided the basis for the land-grant colleges of agriculture. Neither bill said much about research, which was to be a source of some difficulty, but they did create the basic institutions that could foster research. Little was accomplished in forging research efforts until 1887.

The Hatch Act of 1887 was undoubtedly the most important legislative step taken in the development of agricultural research in the United States. In one stroke, it brought about the establishment of the modern network of State agricultural experiment stations (SAES), and it bound USDA and the States together in the process, The Hatch Act set the stage for the Federal-State agricultural system as we know it today. It led to the establishment of an SAES in each State and provided the basis for continuing Federal support. Its impact on the role of research within USDA itself was less immediate.

In February of 1889, USDA was given Cabinet status, but only modest increases were made in Federal agricultural research under the first two Secretaries of Agriculture (excluding N. J. Colman who served only 3 weeks). Under the two secretaries who served from 1889 to 1897, agricultural research in USDA continued at a relatively modest level and was severely handicapped by limited facilities.

The research situation began to change dramatically, however, when James Wilson was named the third Secretary of Agriculture in 1897. Wilson took charge of scientific and regulatory work (previously under an Assistant Secretary), and during his 16-year regime, seven new scientific bureaus were established in the place of the Bureau of Animal Industry, which existed before his arrival. Four of the bureaus were established in 1901 alone: Plant Industry, Forestry (which became the Forest Service in 1905), Soils, and Chemistry. Three were established in subsequent years: Statistics (1903), Entomology (1904), and Biological Survey (1905). Staff increased more than sixfold between 1897 and 1912, and expenditures on USDA research increased from $800,000 in 1900 to $4 million in 1910 (2). Wilson clearly got USDA solidly on its feet in agricultural research.

Early Marketing Studies

From its establishment, USDA had published information about exports and imports of agricultural commodities, and on occasion, sent representatives abroad to protect or extend markets for U.S. farm products. For example, when exports of cattle were being rejected because of charges of infection with pleuropneumonia in 1879, Charles Lynam, a prominent veterinarian, was sent to Britain to determine the validity of the charges. During Secretary J. M. Rusk's administration (1889 to 1893), an agent was sent to Germany and Denmark to promote the exportation of corn. In 1893, a report on world production and distribution of agricultural commodities was submitted to the Secretary of Agriculture by Jacob R. Dodge, a statistician and editor, This publication represented a compilation of information collected over a number of years and was considered to be "the beginning of serious study of world markets for agricultural products by the Department" (19).

Another milestone publication was prepared for the Secretary by George W. Hill in 1897, *Marketing Farm Produce* described the importance of proper handling by the producer, the need for a uniform product, quality, and the value of proper packing. It gave directions for specific commodities and suggested proper types of containers. This publication is considered a landmark, the first marketing publication.

*The material m this appendix draws heavily from the reports, *Marketing Research and Its Coordination in USDA,* by Vivian Wiser and Douglas Bowers; and An *Assessment of the United States Food and Agricultural Research System,* prepared by OTA.

In 1898, the U.S. Industrial Commission was appointed to collect information on immigration, labor, agriculture, manufacturing, and business. This commission published three volumes of testimony and reports on distribution of farm products, agriculture and agricultural labor, and agriculture and taxation. A number of USDA officials appeared before the commission. John Crowell, an economist, prepared the volume 3 on distribution of farm products which was described as the "best book on agricultural marketing available at the beginning of the twentieth century." For two decades after its publication, Crowell's report on marketing set the pattern for many studies made by the SAES. The report's recommendations included inspection and grading of agricultural commodities and livestock, inspection of nursery stock, and establishment of a food section in USDA's Bureau of Chemistry. The implementation of these recommendations meant an expansion of USDA in research and regulatory activities (20).

Formal Marketing Research Organizations, 1900-45

In the early 1900's, a number of SAES, as well as some USDA bureaus, increasingly began preparing studies with an economics orientation. In some instances, they related to the development of an industry, growing and marketing specific crops, livestock, or related products, costs of production, etc. These studies raised problems between those educated as biological and physical scientists and those trained in economics. The new field of agricultural economics was defined as "that branch of agricultural science which treats of the manner or regulating the relations of the different elements composing the resources of the farmer" (8).

With the new interest in economics and in finding markets for the crops that were increasing through scientific research, there came a campaign for an agency within USDA to perform marketing services and research (1). This led to the establishment in 1913 of USDA's Office of Markets, The Office of Markets pursued three main lines of activity: research, regulatory, and service. Research activity included studies of cooperative marketing associations, transportation and storage of farm products, marketing by parcel post, motor transportation of farm products, city marketing and distribution, and marketing methods and costs.

Generally, SAES continued to emphasize production research under the general direction of the Office of Experiment Stations. While research in the SAES had been expanded under the Adams Act of 1906, economics, home economics, and sociological research were underwritten in both the experiment stations and USDA under the Purnell Act of 1925. Efforts to integrate these new areas with production research were initiated but without much success.

Finding outlets for farm products and increasing their utilization were matters of concern in the 1920's and 1930's. The Bankhead-Jones Act of 1935 addressed these concerns by establishing nine regional laboratories to study particular subjects in cooperation with the States: Plant, Soil, and Nutrition (Ithaca, N.Y.), Pasture Research (State College, Pa.), Vegetable Breeding (Charleston, S.C.), Poultry Research (East Lansing, Mich.), Soybean Research (Urbana, Ill,), Sheep Research (Boise, Idaho), Salinity (Riverside, Calif.), Plant-Growth-Regulating Substances, and Photo-Period and Plant Development (Beltsville, Md.).

The Agricultural Adjustment Act of 1938 provided for four additional regional research laboratories (Philadelphia, Pa.; Peoria, 111.; New Orleans, La.; and Albany, Calif.) to develop new uses for surplus agricultural commodities. Although USDA and SAES had previously done some utilization research, this new authorization provided for research into new uses for agricultural commodities that would open new channels for marketing agricultural surpluses.

The Agricultural Adjustment Act of 1938 charged the utilization laboratories "to conduct research into and to develop new scientific, chemical, and technical uses and new and extended markets and outlets for farm commodities and products and by-products thereof. Such research and development shall be devoted primarily to those farm commodities in which there are regular or seasonal surpluses, and their products and by-products." Although the outbreak of war in Europe diverted attention of the new regional laboratories to war-related research, this objective—to carry out research to relieve pressures of surplus farm commodities—held steady in the 1940's and into the 1950's.

A reorganization of USDA in 1938 saw the shifting of commodity divisions and service and regulatory activities from the Office of Markets to the new Agricultural Marketing Service. Within the Agricultural Marketing Service research was redirected to meet wartime needs and to postwar planning; one aspect of this research was marketing economics research. Responsibility for coordinating USDA economics research was given to the Bureau of Agricultural Economics, and responsibility for scientific research was given to the Agricultural Research Administration, in which the scientific bureaus were grouped in *1942*. The new approach was to be aimed at solving marketing problems.

Postwar planning activities had involved a considerable amount of research on the part of USDA and the land-grant colleges at a time when greater emphasis was placed on production and marketing and distribution in an emergency. Members of Congress showed their concern about marketing as bills were sponsored in most sessions to improve marketing procedures for the benefit of farmers and consumers. In *1943,* the House of Representatives authorized its Agriculture Committee to conduct a study of agricultural marketing, but little was accomplished. In *1945,* the work was revived, and a detailed study made. This provided the background for the Research and Marketing Act of *1946 (20).*

Interest in agricultural research increased substantially during World War II. While the war effort focused more attention on research, the substantial rise in agricultural productivity proved how valuable agricultural research could be. This new appreciation of research was visible in many ways. In 1944, the National Research Council established a separate Agricultural Board to consider agricultural questions. Simultaneously, preliminary discussions began that would lead to the establishment of the National Science Foundation.

Congress turned its attention to agricultural research after the war. Because production had jumped by *30* percent during the war, it was widely anticipated that there would be massive surpluses when demand declined, surpluses that would require greater Federal expenditures to keep farm prices from plummeting. Thus, of all the different fields, marketing was considered the most urgent.

Federal aid for production research had achieved impressive gains. If a similar effort were devoted to marketing research, it was reasoned, marketing costs and consumer prices could be lowered and farm prices raised. In addition, research might uncover new ways of utilizing agricultural products that would absorb some of the increased production and hold down the anticipated surpluses. The utilization laboratories authorized in 1938 and diverted to war-related research could once again turn to the purposes for which they were established. The fear of surpluses became the chief motivation behind marketing research (4). By the end of the war, sentiment in Congress was nearly unanimous that the Federal Government should initiate a major new research program with marketing at the center,

The Research and Marketing Act of 1946

The Research and Marketing Act of 1946 (RMA) was a major innovation in the conduct of agricultural research. RMA provided a 5-year research and marketing program with substantial increases in appropriations that would raise the total appropriations from *$9.5* milk in *1947 to $61* million in 1951. RMA funds were intended for new research rather than existing programs. RMA initiated contract work and put greater emphasis than before on regional cooperation, A unique feature of RMA was the combination of private initiatives with government planning. Those closest to the problems at the local level—farmers, industry groups, agricultural colleges, and SAES—had a major input in planning and reviewing research. RMA provided for the first national system of agricultural research advisory committees to meet with Federal officials.

RMA was intended to be a bold push forward for agricultural research. However, instead of reorganizing the entire research program in line with RMA, Congress made it a separate research and marketing program while continuing regular research. From the beginning, there was confusion in funding. In reality, there were three research funds—RMA, regular research, and special research—and the boundaries between them were unclear.

In addition, the complexity of RMA itself added to the difficulty of administration. RMA was the result of two acts that were combined more for convenience than because they represented a unified program. As a result, there were overlapping sections in the act that duplicated appropriations in other sections. The funds were to be divided as follows: 20 percent was to be divided among the States equally; 26 percent was to be allocated by rural population; 26 percent was to be allocated by farm population; and up to 25 percent was to be allocated for cooperative regional research involving two or more SAES; 3 percent was reserved for USDA research administration. At least 20 percent of the money spent under section 9 (all types of research) had to be directed toward marketing research (20).

The administration of RMA was awkward and confusing, Although Congress had intended that marketing research be administered by a new agency within USDA that would combine all marketing functions, USDA kept marketing work divided among several agencies. This division made cooperation difficult. According to Harry C. Trelogan of the Agricultural Research Administration, there was "no clearly defined underlying philosophy as to what should be done other than what is in the Act itself" *(9).* And, as Trelogan pointed out, "it is evident that the Act means different things to different people" (9). There was more concern with coordinating than planning. At no time was a long-range research plan made. Research plans tended to come from a variety of sources and were never fitted into a comprehensive marketing research strategy. Those areas backed by strong pressure groups, such as cotton and fruits and vegetables, developed the strongest research programs.

Despite RMA's slow beginning, the new funding put a strain on the research system. The most immediate problem was finding enough scientists qualified to do marketing work. Early critics of RMA charged that marketing researchers were inadequately trained, tended to confine their work to farms rather than later points in the marketing process, and concentrated on descriptive research to the neglect of theoretical problems (10).

Coordination was especially difficult for marketing research because it involved so many different disciplines. For example, in regional research, many of the regional commodity committees were comprised entirely of agricultural economists. It was not easy to convince scientists used to following their own lines of work to cooperate with others outside their own field (7). Furthermore, there was not a satisfactory way to coordinate between regions, a common situation in marketing work.

Complicating RMA's early years were disagreements between State and Federal officials. USDA wanted RMA used for work of national, or at least regional, interest. SAES marketing advisory committees, however, strongly supported local research under RMA. SAES hoped that some RMA regional research funds would be distributed on a formula basis to make appropriations more predictable, but USDA decided against using a formula. When regional funds were divided among the States, it tended to be spread so thinly that no one experiment station had more than a small part of the work. This arrangement satisfied SAES directors, who wanted funds from as many sources as possible. At the same time, however, it made it difficult to coordinate research and often meant that existing facilities were not adequately used. Furthermore, the States were suspicious of the role of Federal employees in State work, and the Federal Government found it difficult to get the information it needed to support SAES appropriations *(7).*

Finally, some difficulty existed about the place of economics research in the research and marketing program. RMA gave a boost to economics research, but that work was still coordinated separately from postharvest technology. Some SAES directors complained that the two types of research were not well integrated ***(4).***

Marketing Research Coordination, 1953=81

In *1953,* a far-reaching reorganization of USDA came closer to placing marketing research in one agency than any organizational structure had since RMA's enactment. The new Secretary of Agriculture abolished the old bureaus and established a smaller number of agencies to allow more of a team approach to major issues and clearer lines of authority *(6).*

One of the most sweeping changes involved economics research. In *1953,* the Bureau of Agricultural Economics, which had conducted nearly all of USDA's economics research since 1922, was divided between two new organizations: the Agricultural Marketing Service (AMS) and the Agricultural Research Service (ARS). The new ARS was basically a continuation of the Agricultural Research Administration, but the scientific bureau chiefs of the latter disappeared in name and were replaced by deputy administrators (l).

The new AMS pleased supporters of a single marketing administration because it was in line with the intent of RMA, AMS combined the marketing functions of the Production and Marketing Administration with marketing economics research from the Bureau of Agricultural Economics and the marketing areas of Agricultural Research Administration. Within AMS, the Marketing Research Division and the Agricultural Economics Division both reported to the Deputy Administrator for Marketing Research and Statistics, so economic and noneconomic research were grouped more closely than at any time since RMA's establishment (l).

The overall coordination of research was left within ARS, where it had been previously. ARS directly administered both title I and title III of RMA-the SAES funds and the advisory committee structure. Much of this work involved marketing research, which had to be checked against the work conducted by AMS.

Despite the consolidation of most marketing research within AMS, it was clear by the mid-1950's that RMA as a separate program was on the wane. The continuing failure to use the program as a unified research effort led Congress and administrators alike to think increasingly of RMA as simply another part of USDA's research work. After 1950, even the advisory committees established especially to oversee RMA were involved in the entire agricultural research program.

Marketing research prospered under AMS despite RMA's demise. USDA found it easier to obtain appropriations when research was part of an action agency, especially when the administrator had good relations with Congress. Appropriations for marketing research increased from *$3.7* million in 1953 to *$6.9* million in *19.58.*

Despite the reorganization of USDA, coordination of research remained a problem in the 1950's. Regional research was an area of particular difficulty. Regional projects expanded rapidly throughout the 1950's, from 70 active projects in 1950 to 198 in 1958. The regional research program was so popular that it attracted from State sources 21/2 times the amount of Federal investment (11). Under law, the Committee of Nine, composed of two SAES directors from each of the four regions and a home economics representative, had great discretion in allocating funds. To stop the scramble for funds that occurred early in the program, the committee in 1953 adopted a strict formula distribution between regions. Within regions, a formula distribution was also often used. Because each State desired to participate in a maximum number of projects, it was common for the funds to be spread too widely. Projects involving more than one region were not well handled (4).

The ***1960's*** brought new initiatives on research, A reorganization of USDA went in the direction of grouping work by discipline, In the process, marketing research was once again divided. Economics research was reestablished in a separate organization. The Economic Research Service (ERS), created in 1961, brought together economics work in AMS, ARS, and the Foreign Agriculture Service. The AMS Divisions of Marketing Economics Research, Agricultural Economics, and most of marketing development research and the economics research functions of the Transportation and Facilities Research Division were separated from other marketing work and placed in ERS. ERS reported to a director of agricultural economics, whereas the rest of AMS marketing research was under the Assistant Secretary for Marketing and Foreign Agriculture. During this reorganization, the SAES directors also succeeded in getting the State Experiment Stations Division transferred from ARS to a Cooperative State Experiment Station Service under the Assistant Secretary of Federal-State Relations. Thus, marketing research was under three separate individuals in USDA. *

This arrangement was awkward for marketing research. Not only was coordination difficult, but the relationship between marketing and some other types of research was so close that it was hard to draw the line between them. This was especially the case with market quality research where the condition of agricultural produce was related to crop improvement work done by ARS. It was necessary for entomologists to work in both ARS and AMS. In 1964, over the protest of several Senators who felt that marketing research could not be separated from other regulatory and service work, the Divisions of Market Quality and Transportation and Facilities were removed from AMS and placed in ARS (12).

Coordination of research received greater attention as part of a governmentwide effort to better manage scientific information in the 1960's. Dissatisfaction with previous attempts at coordination was evident. Congress favored coordination, and USDA moved in this direction, In 1963 and again in 1965, the Senate Appropriations Committee urged USDA to establish a joint USDA-SAES research review committee to perform a thorough evaluation of all government agricultural research.

USDA created the Agricultural Research Planning Committees to examine long-range research needs in 1965. The committee's 1966 report, "A National Program of Research for Agriculture, " the so-called Long-Range Study, was the most important statement of its type since RMA. In addition to recommending an expanded research program, the committee concluded that the diverse USDA-SAES cooperative research system was better than any single, unified arrangement, but cited the "need for better balance and coordination among the various research efforts. " The report made a number of administrative suggestions, including the appointment of an Assistant Secretary for Science, broader utilization of contracts and grants beyond the land-grant university system, and *use* of ad hoc committees of the Agricultural Research Planning Committee to study particular subject areas on a continuing basis. The Long-Range Study spurred further studies in specific areas. For example, a 1969 report by the Joint Task Force of Marketing and Competition not only asked for more money for marketing economics research, but urged a broader systems-oriented approach that would bridge the gap between disciplines.

During the late 1960's, the balance of power within the research establishment also changed. Advisory committees were put under greater USDA control in 1964, and most were finally abolished in 1969. With the formation of the Agricultural Research Policy Advisory Committee (ARPAC) in 1969, USDA's advice was clearly coming from administrators rather than researchers and farmers as had previously been the case. On the State level, power shifted away from SAES and toward university administrators. Nonagricultural parts of the land-grant colleges and universities had been growing rapidly since before World

● Gains were made when economic researchers were placed in proximity to one another However, this led to an isolation of economics from the other disciplines and is a barrier to interdisciplinary research today.

War II. As SAES were considered less important by legislators, SAES directors had to rely more on university administrators to lobby for funds; however, such administrators often gave a low priority to agriculture.

In the late 1960's and early 1970's, the agricultural research program continued to receive favorable treatment from Congress, but marketing researchers increasingly felt that their role was diminishing. The Long-Range Study did not place a very high priority on marketing work, recommending a decrease from 6 to 5 percent of the total scientist man-years devoted to marketing. Marketing research came under attack in this period for its fragmentation and lack of theoretical underpinning. Much of the debate among agricultural economists in the 1960's centered on the need to broaden the scope of research to meet changing social needs. This concern seemed to leave less of a role for traditional marketing research (14).

Funds for marketing research to SAES increased from $10.6 million in 1965 to $14.4 million in 1971, but this increase was due mainly to the requirement that 20 percent of Hatch Act money be used for marketing research, Furthermore, in order to meet the 20 percent requirement, the definition of what constituted marketing was broadened in the 1960's to include recreation, pesticides, marketing of inputs, and other areas (16).

A survey published in 1973 found that while SAES directors supported greater emphasis on marketing research, heads of agricultural economics departments wanted to reduce marketing research. These attitudes were reflected in a shift of funds from the economics of marketing to marketing technology and a decline in the number of students in marketing economics. Marketing research devoted to technology increased from 39 to 57 percent between 1960 and 1970. Remaining marketing economics research centered around macro and systems problems rather than studies of individual firms which had characterized the research up to this point (5). One area of marketing research that came in for a reduction was wholesaling and retailing research. During the 1960's, USDA repeatedly proposed eliminating this research, but each year Congress restored the funds. By 1970, the administration was witholding some of the money appropriated for wholesaling and retailing research (20).

In 1971, the 25th anniversary of RMA, Congress held hearings to reassess the act and its accomplishments. While USDA officials were elated about the progress under RMA, industry representatives almost uniformly criticized the marketing research program as inadequate and uncoordinated and many asked for a return to a single marketing administration.

In 1972, ARS was reorganized along regional lines in a way that displeased those congressional leaders who favored more centralized control of research. The reorganization came as a surprise. USDA admitted that only about 10 people in ARS knew about it (15).

Following the reorganization and assignment of research to regional offices, ARS established a Marketing Research Coordinating Committee, headed by the National Program Staff, with marketing research representatives from each region. They received recommendations for research, but no increase in funds was requested. The committee was abolished in 1976. An interagency board was also established to coordinate USDA marketing research, but was not utilized. This led the American Farm Bureau Federation to charge that research was fragmented and that production-oriented leadership further reduced the effectiveness of the research program (13).

The report of a special investigation directed by the House Appropriations Committee in 1972 brought out some of the problems that existed in ARS under the new organization. Marketing research in ARS was described as being directed toward increasing marketing efficiency by reducing product losses and costs and by improving methods of quality identification and measurement, including solutions to problems encountered in handling, storage, grading, and distribution of products from farm to retail store. ERS officials reported that its studies covered the complete range of activities from inputs to retailing. Cooperative State Research Service (CSRS) impact had shifted, the report noted, as visits to SAES became less frequent. It became more difficult to terminate unsuccessful projects or to shift priorities, since states would continue projects under other funds.

Metzger's extensive in-house evaluation of the SAES research program in 1973 found marketing research "languishing," with marketing economics especially lacking vigor, He recommended the establishment of marketing research centers at selected stations and closer working relations with government agencies. He advocated that SAES strengthen their ties with their clientele, adopt a systems orientation, and shift emphasis to new problem areas pertaining to marketing organization and structure (20).

A major reorganization in ERS occurred in 1973. The Divisions of Farm Production Economics, Marketing Economics, and Economic and Statistical Analysis were abolished. In their place were established the Commodity Economics and National Economics Analysis Divisions with a less formal structure of groups, and later, program areas in place of branches. Task forces or matrix groups would conduct particular assignments, drawing on personnel from the program areas. A net result was an increase in the staff of the Administrator and the division directors.

Priorities in ERS were shifted from marketing research to other areas. By 1978, the Economics, Statistics, and Cooperatives Service (ESCS) (successor agency to ERS) budget included a proposed decrease of $600,000 for analysis of marketing of farm products, Some activities were slated to be dropped and others cut, reflecting the radically changed nature of the markets. The Federal-States Relations Committee drew up a resolution deploring USDA's role in allowing the marketing efficiency research program to deteriorate to its lowest point since the *1946* RMA. Marketing studies had declined from 1,046 scientist-years in 1969 to a proposed 648 in *1979 (20).*

Marketing research within ARS placed much emphasis on technology, such as improvements in processing and handling and insect detection methods. Marketing research within ERS emphasized market structure and performance, including estimating marketing margins, studies of the sugar industry, the away-from-home food market, the impact of rail reorganization, and a review of marketing orders. Marketing research under the general supervision of CSRS tended to be geared more to scientific rather than economic questions. Thus, in 1975, the SAES worked on such topics as uniform ripening of fruit, apple packing, vacuum-packed beef, and mechanical harvesting.

In 1977, ERS, the Statistical Reporting Service, and the Farmer Cooperative Service were combined into ESCS, cutting the number of agencies reporting to the office of the Secretary, but adding another administrative layer at the top *(15).* In 1978, ARS, the Extension Service, the CSRS, and the National Agricultural Library were consolidated into the Science and Education Administration,

Some of these changes were in line with the Food and Agriculture Act of *1977.* Under this act, USDA was designated as the lead agency for agricultural research. The Joint Council for Food and Agricultural Sciences was established under this act. The Council decided to retain main features of the previous programs, including five ARPAC committees. One of these was the Committee on Coordinating Marketing Research.

Criticism of agricultural research surfaced at the 1977 appropriations hearings, The food industry came together to defend USDA marketing programs scheduled for reduction or termination. USDA defended these reductions by stating that much of the research dropped by USDA would be continued by private industry or the States (13).

Congress restored much of the funding for marketing research that USDA had proposed for deletion. However, the *20* percent earmarking of Hatch formula funds for marketing research was eliminated by Congress. Then, in 1979, selected marketing research functions of the Agricultural Marketing Research Institute, a part of ARS, were transferred to AMS. These included the Animal Products Research, Marketing Operations Research, and the Food Distribution Research Laboratories. The Transportation and Packaging Research Laboratory was transferred to the Office of Transportation, which further added to the problem of coordinating marketing research. In AMS, the units were consolidated in the Market Research and Development Division.

The change of administrations in 1980 shifted the policy direction of USDA. In 1981, the new administration announced a number of organizational changes. Among these was the abolition of the Science and Education Administration. Its constituent parts became separate agencies reporting to the Director of Science and Education (now the Assistant Secretary for Science and Education). ERS was reestablished as a separate agency reporting with the Statistical Reporting Service to the Assistant Secretary for Economics. The Farmer Cooperatives Service was renamed the Agriculture Cooperative Service reporting to the Assistant Secretary for Marketing and Transportation Services.

Reviews of Marketing Research

Because of the debate concerning the virtues of marketing research, three studies were undertaken, In 1977, the Office of Management and Budget asked USDA to undertake a study of marketing research programs to assure that only that research would be performed which would not otherwise be done by the private sector. CSRS was to evaluate research conducted by SAES with Federal funds, ARS was to study postharvest technology research in USDA, and the Industrial Research Institute (IRI) was to conduct a review from the viewpoint of industry.

For its assessment, IRI convened a panel that interviewed representatives of industry and trade associations. Although a limited number of representatives were interviewed and these did not represent a very wide spectrum, their consensus was that any reduction in USDA research would not be supported or assumed by private industry. Many stated that the government should conduct the research for new knowledge in support of national objectives and to satisfy government regulations. The IRI report concluded that the industry believed that Federal research must provide the technical bridge between university science and practical consumer needs (3).

CSRS prepared its evaluation of postharvest technology research in the States. It found that major support was for research on productivity and product quality, but more research was underway on new areas such as health and safety, energy conservation, environmental protection, and reduction of losses. It concluded that the private sector would not finance the research needed to meet societal needs (17).

The report done by ARS summarized research in the various areas and centers with a view of its importance. It concluded that ARS had played an important role in basic research in technological aspects of marketing research and that such research should remain in the public domain with Federal and State financial support (18).

Principal Findings

- The high point in public PHTME research came in the years immediately after the passage of the *1946* RMA, which placed emphasis on this type of research and required that at least 20 percent of Federal research funds authorized under RMA to SAES be directed for PHTME.
- RMA gave a boost to public marketing economics research, but that work was still coordinated separately from postharvest technology research.
- When RMA regional funds were distributed among the States, they were spread so thin that no one SAES had more than a small part of the work. This arrangement made it difficult to coordinate research and often meant that existing facilities were not adequately used.
- USDA in a major reorganization in 1953 came the closest ever to placing PHTME research in one USDA agency. However, in practice RMA was never regarded as a unified research effort.
- The Food and Agricultural Act of **1977, eliminated** the 20 percent requirement under RMA of Federal funds for PHTME research. However, coordination of food and agricultural research supported by Federal funds was written into the law. Since then, PHTME research has nevertheless been deemphasized and dispersed throughout USDA.

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