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RESEARCH AND EDUCATION SUPPORT FOR FOOD AND AGRICULTURE IN THE NATIONAL INTEREST

By

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SUMMARY

Several events during the 1970-80 decade have heightened the concern about whether and how the U.S. food and agriculture sector can continue to sustain adequate productivity growth over the next few decades. This paper assesses: 1) the current situation confronting the U.S. food and agriculture sector, 2) alternative technologies to increase output and/or reduce real food and fiber costs and 3) the implications for research and education programs in the national interest.

The food and agriculture sector made many contributions to the U.S. domestic economy over the past four decades. Paramount among these were the provision of adequate supplies of food and fiber to consumers at reasonable or minimum real prices and labor for activating the ever-expanding nonfarm industrial-commercial sector.

American consumers experienced an unprecedented increase in real food prices during the last half of the 1970-80 decade. However, real personal income also rose so that food costs as a proportion of disposable income remain relatively low--16.5% in 1978 and 1979 compared with 17.3% in 1970 and 20.2% in 1960.

Outmigration of labor from agriculture to nonfarm sectors of the economy declined during the 1970-80 decade. Employment on farms has remained about stable since 1975 and labor from this sector for employment in the nonfarm industrial-commercial sector is rapidly nearing exhaustion.

Several legislative acts were passed and programs were implemented to abate pollution, reduce environmental degradation and/or alleviate potential human health hazards. Environmental regulations impacted on productivity in the food and agriculture sector and altered costs of production, profits and levels of production.

Total farm productivity declined from an average annual growth rate of 2.7% during 1950-1965 to a 1.7% annual rate of increase during 1965-1979.

New demands on the food and agriculture sector emerged during the 1970-80 decade. Total value of agricultural exports (expressed in constant 1979 dollars) more than doubled during the 1970s. The $18.0 billion excess of agricultural exports over agricultural imports in 1979 was a major factor in partially offsetting a $46.7 billion trade deficit in non-agricultural accounts.

Both the food and agriculture sector and the general economy are subject to greater instability because of a growing international economic interdependence. Government policies for achieving price stability within countries, technological development and weather variability worldwide have caused international price instability and increased risk to the U.S. food and agriculture sector. Also, food has become a strategic weapon of the U.S. government in world political affairs.

A major concern is the security of the future food supply and its costs due to declining rates of increase in agricultural productivity, environmental regulations, rapidly escalating costs of petroleum and petro-chemicals and increasing effective demand worldwide for highly preferred foods (e.g., pork, poultry, beef and dairy products).

At the very heart of existing U.S. food and agriculture production-processing-distribution techniques is a reliance on an abundant, inexpensive supply of fossil-based energy inputs. Consequently, since the Arab oil embargo of 1973-74 and the end of cheap crude oil, the food and agriculture system entered into a period of great uncertainty with respect to changes in the relative prices of labor, land and energy.

America's food and agriculture sector must make major technological adjustments during the 1980s. Without such adjustments, it will be weakened seriously, and its contribution to the domestic economy will be diminished.

Future success of America's food and agriculture system lies in the development and application of new energy-efficient technologies. These include: 1) improvement of existing production-management systems for food and agriculture to conserve fossil-based energy, 2) development of alternative sources of energy for agriculture and forestry and 3) development of new energy-efficient technologies for food and agriculture.

Greater efforts must be placed on conserving fossil-based energy through changes in production and cultural practices within existing technologies. Applied research and extension efforts need to be focused on reducing or eliminating unnecessary production practices, including land preparation, planting, cultivating, irrigating, fertilizing, pesticide applications and harvesting techniques.

Attention also must be turned to other sources of energy and development of technologies to efficiently use these energy sources.

A prerequisite for determining the potential contribution of agriculture and forestry to the production of usable nonfood energy and industrial chemicals is the investigation of actual current and expected future costs with present bio-mass production, digestion, distilling and refinery technology.

A second line of investigation is assessment of the potential for reducing costs of usable energy and chemicals from agricultural and forestry sources. These assessments include the prospects of substantial energy yield increases through improved digestion, distillation and refining techniques, as well as increases in raw product yields of conventional or exotic species of plants.

Plant residues and animal wastes are both potential sources of animal feed and sources of usable energy and industrial chemicals. Bio-mass conversion of plant and animal wastes that are not used for food, animal feed, wood products or maintenance of land quality and productivity allows the joint production of food, feed or wood products and industrial chemicals.

Great long-run potential exists for development of genetically superior plants and animals. Basic and applied research to add to the technology reservoir for the food and agriculture sector include: 1) analysis and synthesis of growth regulators, enzymes and hormones for improved productivity of plants, 2) establishment of key linkages to hasten application and exploitation of recently acquired knowledge about photosynthesis, nitrogen fixation and molecular genetics and 3) transfer of basic recombinant DNA knowledge to practical, commercial technologies. Other long-run potentials include: 1) development of improved methods of irrigation, 2) development of new varieties of plants less reliant on fertilizers and pesticides, more tolerant to drought, salt, frost or acid rain, more resistant to insects, diseases and other pests, and possessing higher nutritive quality and safety from naturally occurring toxins and 3) application of recent basic molecular genetics, cell culture, hormone and growth regulator research to improve genetic capacity, disease resistance and reproductive efficiency for animal production and for increased efficiency of feed utilization.

Integrated crop management systems that reduce biological stress on plants can realize huge savings in the use of pesticides, fertilizers, fuels, etc. Environmental concerns emphasize the need for integrated crop management systems to reduce losses caused by pests, reduce costs of pest control and other production practices, reduce environmental damage from pesticides and fertilizers and maintain profitability of production from superior crop management systems.

Exchange and transportation systems need to be streamlined. Exchange (i.e., transfer of ownership and price discovery), assembly on the farm and distribution of farm commodities and final consumer products are vital components of an efficient food and agriculture system. Electronic exchange systems can widen the scope of markets available to the primary farm or forestry producer, enhance the price discovery mechanism and provide both buyers and sellers with timely information on prices, quantities and physical characteristics of products. Electronic exchange systems also could be integrated with the transportation system needed to assemble and distribute food, fiber and wood products.

The publicly funded system of research, extension and higher education in the food and agricultural sciences has been a prominent contributor to productivity growth in food and agriculture. The development and dissemination of information on new energy-efficient technologies for food and agriculture are vital because food and agriculture has become the major stabilizing sector in the domestic economy.

Scientific and technical progress must be enhanced now if the technological reservoir is to be continually replenished. This requires redirection of existing research and education efforts and substantial new investments in the food and agricultural sciences.

A rapid transition to new energy-efficient technologies cannot occur without substantial increases in public funding for the food and agricultural sciences. Growth in public investments in agricultural research and education since the mid 1960s has dropped alarmingly relative to the previous two decades (measured in terms of constant 1967 dollars). Federal funding of food and agricultural research through the USDA (i.e., SEA-AR, SEA-CR, ESCS, FS) and other federal agencies has increased only slightly since 1967 despite rapid growth in agricultural exports and food crises of global dimensions in the mid 1960s and early 1970s.

In the past, new technological discoveries from the national food and agricultural research effort and the adoption of these technologies by business firms provided increased efficiency to offset rising costs. The benefits to society were actual decreases in real food costs to American consumers. However, unless a dramatic increase in real public funding of agricultural research and education is made, American consumers may experience substantial increases in real food costs. The current level of public investment in the food and agricultural sciences is insignificant relative to the benefits derived by the general public.

INTRODUCTION

Several events during the 1970-80 decade impacted sharply on the U.S. food and agriculture system. They include: 1) the increasing interdependence among the basic industries of agriculture and forestry and other sectors of the domestic and world economies, 2) the increasing dependence of the USA on foreign sources of petroleum, the cartelization of major foreign crude oil suppliers under OPEC, and an increased vulnerability to world-wide political unrest, 3) the rapidly expanding export market for farm food and feed commodities and the reliance on farm commodity exports to help offset a growing deficit in international trade, 4) further commercialization and industrialization of the food and agriculture sector and 5) the increasing social awareness and demands for improved environmental quality and human health, which led to public regulations that impact on the food and agriculture system.

These events have increased the extent to which U.S. producers and consumers of food, fiber and forestry products are affected by national and world economic, social and political conditions. They also have provided the basis for heightened concern about the adequacy of our current technology base. The basic concerns are whether and how the food and agriculture system can continue to sustain adequate productivity growth over the next few decades in the face of a large and increasing array of constraints and escalating costs.

This paper assesses: 1) the current situation confronting the U.S. food and agriculture system, 2) alternative technologies to increase output and/or reduce real food and fiber costs and 3) the implications for research and education programs for food and agriculture that are in the national interest.

U.S. FOOD AND AGRICULTURE SECTOR IN AN INTERDEPENDENT WORLD

Role of Food and Agriculture in the Domestic and World Economies

The role of the U.S. food and agriculture sector in the domestic and world setting changed markedly during 1970-80. The prior period (1950-1972) was one of relatively low prices of capital, petroleum-based energy, land and fertilizer, resulting in the development of a food and agriculture system that is based on intensive use of these resources. Aggregate demand for agricultural and forestry output increased steadily as population, income and export demand increased. The post World War II technology was characterized by increasing returns to size resulting in lower costs per unit of output for the larger production, processing, marketing and distribution firms. The food and agriculture sector contributed to growth of the domestic economy during the three decades prior to 1970 through the provision of 1) adequate supplies of food and fiber to consumers at reasonable and declining real prices, 2) labor for activating the ever-expanding nonfarm industrial-commercial sector, 3) nonhuman capital for the development of other sectors of the economy, 4) raw materials, including wood and forest products, for processing and fabrication, 5) open space and recreational opportunities for urban residents and 6) markets for goods and services produced in the nonfarm industrial-commercial sector. Also, food products were used in foreign assistance programs to help alleviate hunger and malnutrition in the underdeveloped nations.

The food and agriculture sector continued to make these contributions to the domestic and world economies during 1970-80. But some of the contributions diminished in magnitude and new demands on the food and agriculture sector emerged. Real prices for food and agricultural products increased. However, real personal income also rose so that food expenditures as a proportion of disposable income remain relatively low--16.5% in 1978 and 1979 compared with 17.3% in 1970 and 20.2% in 1960 (Figure 1). Outmigration of labor from agriculture to nonfarm sectors of the economy declined during 1970-80. Employment on farms decreased an average of only 83,000 per year during the 1970s compared with average annual declines of 273,000 during the 1960s and 287,000 during the 1950s. Employment on farms has remained about stable since 1975 and labor from this sector for expansion of the nonfarm industrial-commercial sector is rapidly nearing exhaustion (Figure 2).

Several legislative acts were passed and programs were implemented to abate pollution, reduce environmental degradation and/or alleviate potential human health hazards. These programs impacted directly on the food and agriculture system. Among these were the Federal Air Quality Act of 1970, the National Environmental Policy Act of 1970, the Federal Water Pollution Control Act (1972), the Federal Environmental Pesticide Control Act (1972), the Toxic Substances Control Act (1976), the National Pollution Discharge Elimination System (1976) and the Clean Water Act (1977). Agricultural activities that are impacted by these regulations include pest control, soil and water conservation, feedlot waste disposal and nonpoint pollution abatement. The impacts of environmental regulations have been to alter costs of production, profits and levels of production.

The rate of increase in agricultural productivity declined in the late 1960s and 1970s--in particular, crop yields per acre and livestock production per breeding unit increased at much slower rates than in the 1950s and early 1960s. Crop production per acre increased at an average annual rate of 3.0% during 1950-1965. The rate of increase was only 2.1% annually during 1965-1979. The average annual rate of growth in livestock output per breeding unit declined from 2.2% during 1950-1965 to 1.3% during 1965-1979. Farm labor productivity also exhibited a decline in its annual growth rate, from 10.8% in 1950-1965 to 8.4% during 1965-1979. The effect of these changes in components of farm productivity was that aggregate farm output per unit of total factor input declined from an average annual growth rate of 2.7% during 1950-1965 to a 1.7% annual rate of increase during 1965-1979 (Figure 3).

New demands were made on the food and agriculture sector during the 1970s. Farm-produced food and feed commodities became a major source of export earnings. Total value of farm exports grew steadily in the 1960s as U.S. agriculture turned to the commercial world market as a viable outlet for its growing production. But with successive devaluations of the U.S. dollar and the shift to floating exchange rates in the early 1970s, coupled with the rapidly growing effective demand for food abroad, total value of agricultural exports (expressed in constant 1979 dollars) more than doubled during the 1970s (Figure 4). The $18.0 billion excess of agricultural exports over agricultural imports in 1979 was a major factor in partially offsetting a $46.7 billion trade deficit in nonagricultural accounts. Domestic U.S. consumers benefit from this increased export capability of the food and agriculture sector. In particular, farm-produced food and feed exports help pay for imports of petroleum, minerals, appliances, motor vehicles and a variety of other raw materials and finished products that are cheaper than domestic products.

The change in the structure of world trade is of major importance to the food and agriculture sector and to the general economy. Both are subject to greater instability because of a growing international economic interdependence. Government policies for achieving price stability within countries, technological development and weather variability worldwide have caused international price instability and increased risk to the U.S. food and agriculture sector. Also, food has become a strategic weapon of the U.S. government in world political affairs.

A major concern is the security of the future food supply and its costs due to declining rates of increase in agricultural productivity, environmental regulations, rapidly escalating costs of petroleum and petro-chemicals and increasing effective demand worldwide for highly preferred foods (e.g., pork, poultry, beef and dairy products). These phenomena--combined with general price inflation in the domestic economy--have resulted in unprecendented rates of increase in food prices to American consumers during the last half of the 1970-80 decade. But rising costs of food have been offset by rising personal income (Figure 1). Those particularly hardpressed include persons and households with low incomes and relatively fixed incomes. Even so, food costs to all American consumers remain low compared with other developed nations. The 16.4% of private consumption expenditures spent on food in the U.S. in 1977 contrasts sharply with the 23.5 to 42.1% required in the Western European countries (Figure 5).

Characteristics of U.S. Food and Agricultural Technology

Petroleum emerged as the dominant, low-cost source of energy and raw material for industrial chemicals during the two mid-quarters of the 20th century. It played a major role in shaping the structure of the U.S. food and agriculture system during this period. A food and agriculture production-distribution system was developed that is highly dependent on use of petroleum and petro-chemicals as sources of energy for mechanical power, electrical power, climate modification and raw material for chemical fertilizers and pesticides.

Abundant supplies of inexpensive diesel fuel, gasoline and natural gas fostered a rapid transition from animal power to mechanical power during the first half of the 20th century. Mechanization and crop specialization on a regional geographical basis tended to offset rising labor costs to agriculture. Labor productivity in farm production activities grew rapidly. Use of chemicals (fertilizers, herbicides and pesticides) derived from the petro-industry boosted yields. Agricultural productivity was further advanced through development of new plant varieties and hybrid seeds that used fertilizers effectively, that were not affected by herbicides and pesticides and that were amenable to large-scale mechanization.

These mechanical and bio-chemical technological advances were augmented further by increased use of petroleum and electrical energy for irrigation, crop drying and refrigeration, which reduced the risk of crop failure or spoilage. Also, the national interstate highway system allowed production inputs and farm and forest products to be transported long distances at relatively low costs. The U.S. food and agriculture system was transformed from a subsistence agrarian system to a highly industrialized-commercialized system. It became an integral part of the vast industrial-commercial complex that characterizes the U.S. economy. The fact that science and technology contributed substantially to this progressively more efficient food and agricultural production-distribution system is well documented.

Existing U.S. food and agriculture production-processing-distribution techniques rely on an abundant, inexpensive supply of fossil-based energy inputs. Consequently, since the Arab oil embargo of 1973-74 and the end of cheap crude oil, the food and agriculture system entered into a period of great uncertainty with respect to changes in the relative prices of labor, land and energy. Fertilizers, pesticides, farm trucks and farm tractors and machinery require large amounts of fossil fuel in their manufacture and distribution. Rising oil, natural gas and coal prices contributed to a more than doubling of costs for most of these vital farm production and transportation inputs during the 1970-80 decade (Figure 6). By the most conservative estimates, world oil and natural gas prices will double again by 1985. The U.S. Department of Energy forecasts are for prices of oil, natural gas and electricity to rise 17, 21 and 12% per year, respectively, over the 1979-1984 period.[1/] These projections are based on assumptions of continuation of current decontrol legislation and rising prices for imported crude oil.

America's food and agriculture system is vulnerable to these petroleum price increases. The nation's food and agriculture sector—the largest industry in the United States, with a total retail value of over $350 billion and employing 20% of the civilian work force in 1979--must make major technological adjustments to remain competitive in the world market. Without such adjustments during the 1980s the food and agriculture system will be weakened seriously, and its contribution to the domestic economy will be diminished.

[1/] U.S. Department of Energy, Forecasts 1979-84, Data Resources Inc., August, 1979.

A major concern from a longer run perspective is the ability of world agriculture to provide and maintain adequate diets for an ever-increasing population with rather fixed areas of cropland. This requires new approaches for increasing the production of food. The world food supply currently depends largely on four species of plants (maize, wheat, rice and soybeans) and three species of animals (cattle, swine and chickens). Science and technology have been directed predominantly to enhancing the output of these plant-animal species.

Another area of concern in responding to domestic and world food, fiber and wood needs is the adverse effect of natural resource depletion and quality of the environment deterioration. Paramount among these concerns is the need to maintain a productive resource base for future generations. Competition between the food and agriculture sector and nonagricultural users of land, water and other resources can become even more intense in the future as these resources are used more fully.

ALTERNATIVE TECHNOLOGIES FOR INCREASING U.S. FOOD AND AGRICULTURAL PRODUCTIVITY

Future success of America's food and agriculture system lies in the development and application of new energy-efficient technologies. A transition must be made from existing fossil-fuel based production and distribution methods to more energy-efficient technologies, assuring a continuing competitiveness without disruption to the nation's economy. These new energy-efficient technologies must reduce the need for fossil fuels by combining even tighter conservation measures for fossil-fuel based energy with adaption of alternative energy sources. Research, extension and education programs must be enhanced and redirected to systematically remold existing technology to meet the changing economic conditions.

Several on-going research, extension and education programs are designed to realize this goal of ushering in a new era for food and agriculture. These include: 1) improvement of existing production-management systems for food and agriculture to conserve fossil-based energy, 2) development of alternative sources of energy for agriculture and forestry and 3) development of new energy-efficient technologies for food and agriculture.

Improve Existing Production-Management Systems

Prospects of substantial increases in prices of fossil-based energy over the next five years pose uncertainties for agricultural firms, particularly in the ways they are organized and managed. The eventual effects will most likely be evident in the mix of resources used in farming, ranching and forestry. Higher relative prices for energy will stimulate producers to seek ways to adjust the combinations of resources they employ in production. The extent of price changes, the energy efficiencies of available technologies and the substitutability among resources within these technologies will influence the choices regarding resource use. The resource mix may be characterized by increasing emphasis on land and labor. But major efforts must be placed on conserving fossil-based energy through changes in production and cultural practices within existing technologies.

Applied research and extension efforts need to be focused on reducing or eliminating unnecessary production practices, including land preparation, planting, cultivating, irrigating, fertilizing, pesticide applications and harvesting techniques. No-till, reduced-tillage, timing of plant nutrient, pesticide and water applications, and management of these production inputs to increase efficiency in plant growth, coupled with economically feasible alternatives for pest control, plant nutrient sources, etc. are but a few examples of the options needing greater emphasis.

Although improvements in production-management systems to conserve energy used in producing food, fiber and wood are necessary, such improvements are short-term, stop-gap measures for maintaining productivity and efficiency in farm, forest and fiber production. Attention must be turned to other sources of energy and development of technologies to efficiently use these energy sources if the food and agriculture system is to sustain sufficient growth to meet domestic and expanding world demands.

Develop Energy Substitutes for Petroleum and Petro-Chemicals

There are numerous alternative sources of energy, including grain, sugar and root crops, oil crops, crop and animal wastes and a host of trees, shrubs and other plants. It is technically possible to convert all of these materials into usable fuels for internal combustion engines, electricity, direct heating, feedstock for industrial chemicals, etc. Such fuels generally would possess the same physical characteristics as petroleum or natural gas. A very legitimate question--in view of rapidly escalating prices and apparently dwindling reserves of petroleum--is "Why don't we get on with it?"

At least two major reasons why private industry (including the farm and forestry sector) does not "get on with it" are: 1) the actual cost of acceptable and usable energy products from agricultural and forestry sources are high compared with petroleum and 2) there is a high degree of uncertainty concerning existing reserves of petroleum and who will control these reserves. In addition to probable higher production costs, production of usable energy and chemical feedstocks from agricultural and forestry sources requires a massive infusion of new capital--in the form of machines, distilleries, refineries, etc. This is high risk capital that is not readily available in the private sector. Capital that might be available probably would be accessible only at high interest costs.

The fact that the actual cost of producing usable energy and industrial chemicals from petroleum is less than from alternate sources provides an economic disincentive for any would-be competitor. It is doubtful that the farm and forestry sector possesses the countervailing power or financial reserves to combat the economic power of the petro-industry. There apparently is a substantial equity in land and farm buildings but committing it to an infant, nonfood, energy industry would be a high risk venture. A prerequisite for determining the potential contribution of agriculture and forestry to the production of usable nonfood energy and industrial chemicals is the investigation of actual current and expected future costs with present bio-mass production, digestion, distilling and refinery technology. These costs then should be compared with actual costs of energy from petroleum sources, coal, direct solar, wind, water, geothermal, nuclear, etc. This would establish the current costs position of agriculture and forestry as a source of usable energy and industrial chemicals relative to the alternative sources. A second line of investigation is assessment of the potential for reducing costs of usable energy and chemicals from agricultural and forestry sources. These assessments include the prospects of substantial energy yield increases through improved digestion, distillation and refining techniques, as well as increases in raw product yields of conventional or exotic species of plants.

These approaches also are likely to provide only short-run, stopgap measures for food and agriculture. Development will be undertaken in the short-run only if economic feasibility studies are promising in terms of reasonable cost of usable energy and industrial chemicals from agricultural and forestry sources. Government underwriting might be involved where national security is important. The studies of the potential for nonfood energy and industrial chemicals from agricultural and forestry sources also would need to investigate the potential impacts on food, fiber and forest product supplies and costs.

Development of New Energy-Efficient Technologies

There might be cropland available for production of nonfood energy and industrial chemicals in the short-run, but there still remains the question of long-run sustainability. This is particularly critical when massive capital investments of a highly durable nature are required. Three potential lines of investigation for maintaining long-run productivity in the food and agriculture sector appear to be 1) the conversion of plant residues and animal wastes into usable energy and industrial chemicals, 2) the development of plants and animals with superior genetic characteristics and 3) development of improved commodity exchange and transportation systems.

Plant residues and animal wastes are both potential sources of animal feed and sources of usable energy and industrial chemicals. These sources may or may not compete directly with agriculture and forestry for land and capital resources. Crops produced on farm and forest lands for bio-mass conversion would compete directly for resources used in food, feed, fiber and wood production. Crop residues harvested for energy production are normally left on the land to return nutrients to the soil and maintain organic matter content. Their presence reduces erosion, enhances water-holding capacity of the soil and reduces losses of nutrients, pesticides and organic matter through run-off. Thus, bio-mass conversion of crop residues from agricultural lands can have a detrimental effect on land quality and future production potential. Bio-mass conversion of plant and animal wastes that are not used for food, animal feed, wood products or maintenance of land quality and productivity allows the joint production of food, feed or wood products and industrial chemicals. Thus, the market value of the joint product chemicals in effect reduces the cost of energy. Bio-mass conversion of wastes is a potential for using our natural resources as a source of energy and industrial chemicals to replace fossil-based fuel.

Great long-run potential exists for development of genetically superior plants and animals. Basic and applied research to add to the technology reservoir for the food and agriculture industry include: 1) analysis and synthesis of growth regulators, enzymes and hormones for improved productivity of plants, 2) investigation of cell membranes, especially relating to the movement of hormones and toxins into and from cells of plants, 3) establishment of key linkages to hasten application and exploitation of recently acquired knowledge about photosynthesis, nitrogen fixation and molecular genetics and 4) transfer of basic recombinant DNA knowledge to practical, commercial technologies leading to new enzymes, nitrogen fixation in nonleguminous plants and advances in immunology and other means of disease control. Other long-run potentials include: 1) development of improved methods of irrigation to provide timely applications of water to plants and reduce run-off and leaching effects of current irrigation practices, 2) development of new varieties of plants less reliant on fertilizers and pesticides, more tolerant to drought, salt, frost or acid rain, more resistant to insects, diseases and other pests, and possessing higher nutritive quality and safety from naturally occurring toxins and 3) application of recent basic molecular genetics, cell culture, hormone and growth regulator research to improve genetic capacity, disease resistance and reproductive efficiency for animal production and for increased efficiency of feed utilization.

Integrated crop management systems can reduce biological stress on plants and also realize huge savings in the use of pesticides, fertilizers, fuels, etc. Integrated crop management systems developed around integrated pest management (IPM) programs use biological and cultural practices along with chemical controls of pests. Biological control is the cornerstone of IPM programs as all control components must be complementary with and maximize the effectiveness of biological control agents (e.g., beneficial insects or organisms that prey on the pests) that exist in nature. Environmental concerns emphasize the need for integrated crop management systems to reduce losses caused by pests, reduce costs of pest control and other production practices, reduce environmental damage from pesticides and fertilizers and maintain profitability of production from superior crop management systems.

Research and education are needed to streamline exchange and transportation systems. Exchange (i.e., transfer of ownership and price discovery), assembly on the farm and distribution of farm commodities and final consumer products are vital components of an efficient food and agriculture system. In fact, an effective exchange system is essential to adoption of the new production technology that accompanies specialization in production.

Modern communications technology has not been exploited fully in the food and agricultural commodities exchange systems. Electronic exchange systems could provide most of the attributes of a perfectly competitive market. It can widen the scope of markets available to the primary farm or forestry producer, enhance the price discovery mechanism and provide both buyers and sellers with timely information on prices, quantities and physical characteristics of products.

Electronic exchange systems also could be integrated with the transportation system needed to assemble and distribute food, fiber and wood products. Rising energy and labor costs will require a better coordinated, more efficient transportation system. Basic information to undergird an electronic exchange system, especially the evaluation of the capabilities and costs of alternative exchange systems and/or modifications to existing ones, is required.

IMPLICATIONS FOR RESEARCH, EXTENSION, AND HIGHER EDUCATION

The primary functions of science and education are to develop and disseminate information useful to the food and agriculture industry and to the general public. Past performance of these functions by the scientific community has helped food and agriculture reach its present high state of productivity and efficiency. Future performance of these functions will be even more critical as our food and agriculture system faces rising costs, increasing competition for resources, more constraining regulations and more volatile markets. The primary means for coping with these events is an ever-improving technology. Future prosperity of this nation will come mostly through development and use of scientific knowledge and technology.

The system of publicly funded research, extension and higher education pertaining to food and agriculture has been in place for a long time. It contains a wealth of very exact expertise that is stable and cannot be changed substantially in the short-run. The public has reaped benefits from investments in this sytem far in excess of the costs. The system has demonstrated its ability to respond to the public demands placed on it. Joint efforts by groups of state institutions and federal agencies have proven to be the most effective and often the only practical approach to some problems of regional and national interest. The research and education programs of the state institutions and the in-house research of the U.S. Department of Agriculture are complementary and interdependent.

Developing Information

Research forms the foundation for technological progress. Future progress will depend, perhaps more than ever before, on the development of new knowledge and new understanding of: 1) how biological, mechanical, economic and social systems function and 2) how modifications or innovations can make the systems function more effectively for the betterment of humanity. The undergirding knowledge base and subsequent innovations are essential to economic development and rising affluence of the populace.

An efficient food and agriculture system requires the input of numerous sciences. It is exceedingly difficult to meaningfully array sciences, research and education programs or research problem areas in order of importance. A body of scientific knowledge is evolutionary--it is not planned but evolves in bits and pieces. The important ingredients are imagination and perserverance. Theory has to precede empirical verification and the evolution of knowledge, neither of which can be ordained.

Each state or region faces distinct problems in the development of technologies for food and agriculture because of differences in climate, soil, market outlets and other conditions. Much of the applied research to develop new energy-efficient technologies will have to be done on a state or area basis.

Disseminating Information

Education is one of the pillars on which modern life is built. A future without improved education is hard to contemplate because the finest technology is sterile until it is disseminated to the people who can use it. Both extension and formal education are channels for dissemination of knowledge and information.

Extension has played a momentous role in the development of food and agriculture. Its function of bridging the gap between development and application of new technology is even more important today. One continuing important function is keeping producers and agribusinessmen informed of new and improved techniques, market conditions and the growing array of rules and regulations within which the industry operates.

In addition to its role in technical agriculture, extension performs a valuable public service by helping society at large understand and deal more effectively with industrywide and community problems. Decisions on these problems transcend decisions by individuals relating to single businesses; they are group decisions which in total set the stage within which individuals operate. Extension helps assure that the relevant factors of each issue are made known to people in whose hands final decisions rest.

Formal teaching of college students at the undergraduate and graduate levels develops the requisite manpower for creating new knowledge and for disseminating and using information. The directions of change for food and agriculture emphasize the growing need for even more competent technicians and managers in the industry of the future. Substantial improvement in the quality of the human agent through education becomes of greater importance because of complementarities between the skill levels of the human agent and the new knowledge generated by research. Individuals have to process the new technical knowledge and adapt it to particular situations. Their ability to do this improves as their level of formal education increases.

Scientists who develop and disseminate knowledge also must be trained. Much of the graduate training in institutions of higher education is designed for this function. The growing need for both graduate and undergraduate teaching of college students places a special responsibility on the colleges of agriculture in Land-Grant and other state universities. It requires alteration of academic programs to include special courses and interdisciplinary training in such fields as integrated pest management, agribusiness, energy conservation and use and animal and human nutrition.

Increasing numbers of agriculture students at the college level have no previous experience in food and agriculture. Many with a genuine desire for careers in food and agriculture lack practical experience. New programs are required to provide specialized training for urban and "nonfarm" students to assure that, as college graduates, they know first hand the problems of food and agricultural production and marketing in addition to principles and theory.

Some facets of the food and agriculture system face current and future shortages of graduates in food and agricultural sciences. The Manpower Assessment Project of the Science and Education Administration analyzed the occupational structure of the food and agriculture sector and the extent to which higher education is providing the specific types of graduates required by the industry.[2/] Supply and demand for trained manpower were projected for the 1985-86 period in several occupational clusters. Shortages of trained manpower were identified for administrators, managers and financial advisors (particularly those individuals with master's and doctoral degrees) and for manufacturing and processing scientists and engineers. A strong market was projected for scientific and professional specialists and for college and university educators in the food and agricultural sciences. Modest increases in employment opportunities were projected for sales and service representatives and purchasing agents, and for miscellaneous agricultural specialists (e.g., farm implement mechanics). More professionals will be required to manage the fewer but larger firms of the food and agricultural industry. Government agencies and extension will demand more competent people to deal with the growing body and complexity of rules and regulations and with tougher technical, economic and social problems. A higher state of knowledge will be required for success in the food and agriculture system of the future.

[2/] U.S. Department of Agriculture, Science and Education Administration, Office of Higher Education, Graduates of Higher Education in the Food and Agricultural Sciences: An Analysis of Supply/Demand Relationships, Misc. Publication 1385, July, 1980.

Public Investment in Research and Education

Past growth in food and agriculture has come from two sources--increases in the volume of production resources used to produce food, fiber and wood, and productivity increases due to improved efficiency in the use of resources. The publicly funded system of research, extension and higher education in the food and agricultural sciences has been a prominent contributor to productivity growth in the food and agriculture system.

We must concentrate on efficiency of resource use as we look to the future. We must find ways to get more food, fiber and wood from available resources at less cost--whether measured in dollars, energy, environmental impacts or some other way. We must enhance scientific and technical progress now if the technological reservoir is to be continually replenished.

These needs require redirection of existing research and education efforts and substantial new investments in the food and agricultural sciences. A recent study concluded that the annual rate of productivity growth in agriculture has been approximately 1.5% per year for the past 50 years but that it took an alarming drop in the late 1960s and early 1970s. Although productivity growth has recovered in recent years, this study concluded that it may drop to 1.1% or lower between now and the year 2000 if no substantial increases in real investments in agricultural research and education are made and no new and unprecendented technologies emerge.[3/]

A second study examined the impacts on food costs to American consumers that would result from allowing a 10% lower funding base (in terms of real dollar support) to occur for agricultural research and education. The cumulative effects for the two decades of 1980-2000 result in productivity lagging behind its historical rate of growth.[4/]

This lag in productivity would result in lower rates of expansion in the quantity of food produced and consumed and in higher prices each year. The costs to the American consumer far outweigh the savings in government expenditures for agricultural research and education. A net social cost of $10.8 billion in 1977 dollars over the two decades was determined.

In essence, the U.S. food and agriculture system is at a crossroads. Current technologies can be continued with a resulting drop in the productivity growth rate and competitiveness worldwide. Or new energy-efficient technologies can be developed to keep this nation's food and

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3/ Yao Chi Lu, Phillip Cline, and Leroy Quance, Prospects for Productivity Growth in U.S. Agriculture, Agri. Econ. Report No. 435, ESCS, USDA, Washington, DC, September, 1979.

4/ Fred C. White, Joseph Havlicek, Jr., and Daniel Otto, Agricultural Research and Extension Investment Needs and Growth in Agricultural Production. A.E. 33, Dept. of Agri. Econ., VPI & SU, November, 1978.

agriculture system the most important in the world. These new technologies are vital because the food and agriculture sector has become the major stabilizing and growth sector in the domestic economy.

A rapid transition to new energy-efficient technologies cannot occur without substantial increases in public funding for the food and agricultural sciences. Growth in public investments in agricultural research and education since the mid 1960s has dropped alarmingly relative to the previous two decades. Total public funding for agricultural research has increased only 1.9% annually since 1967 compared with a 3.9% annual compound growth rate during 1939-1967, measured in terms of constant 1967 dollars (Figure 7). Federal funding of food and agricultural research through the USDA (i.e., SEA-AR, SEA-CR, ESCS, FS) and other federal agencies has increased only slightly since 1967 despite rapid growth in agricultural exports and food crises of global dimensions in the mid 1960s and early 1970s.

Failure to invest in scientific and technical progress will result in slower productivity growth in the food and agriculture sector. Slower rates of expansion in farm output will diminish the contribution of the U.S. food and agriculture sector to the domestic economy and export trade. This will eventually worsen our deficit balance of payments and dampen the role of food as a strategic weapon of the government in world political affairs.

In the past, new technological discoveries from the national food and agricultural research effort and the adoption of these technologies by business firms provided increased efficiency to offset rising costs. The benefits to society were actual decreases in real food costs to American consumers when viewed as a percentage of disposable income. However, unless a dramatic increase in real public funding of agricultural research and education is made, American consumers may experience real food costs more in line with those of other developed countries. Higher real food costs result in a disproportionate burden on low-income families who must spend more of their income for food. Certainly, the current level of public investment in the food and agricultural sciences is insignificant relative to the benefits derived by the general public.

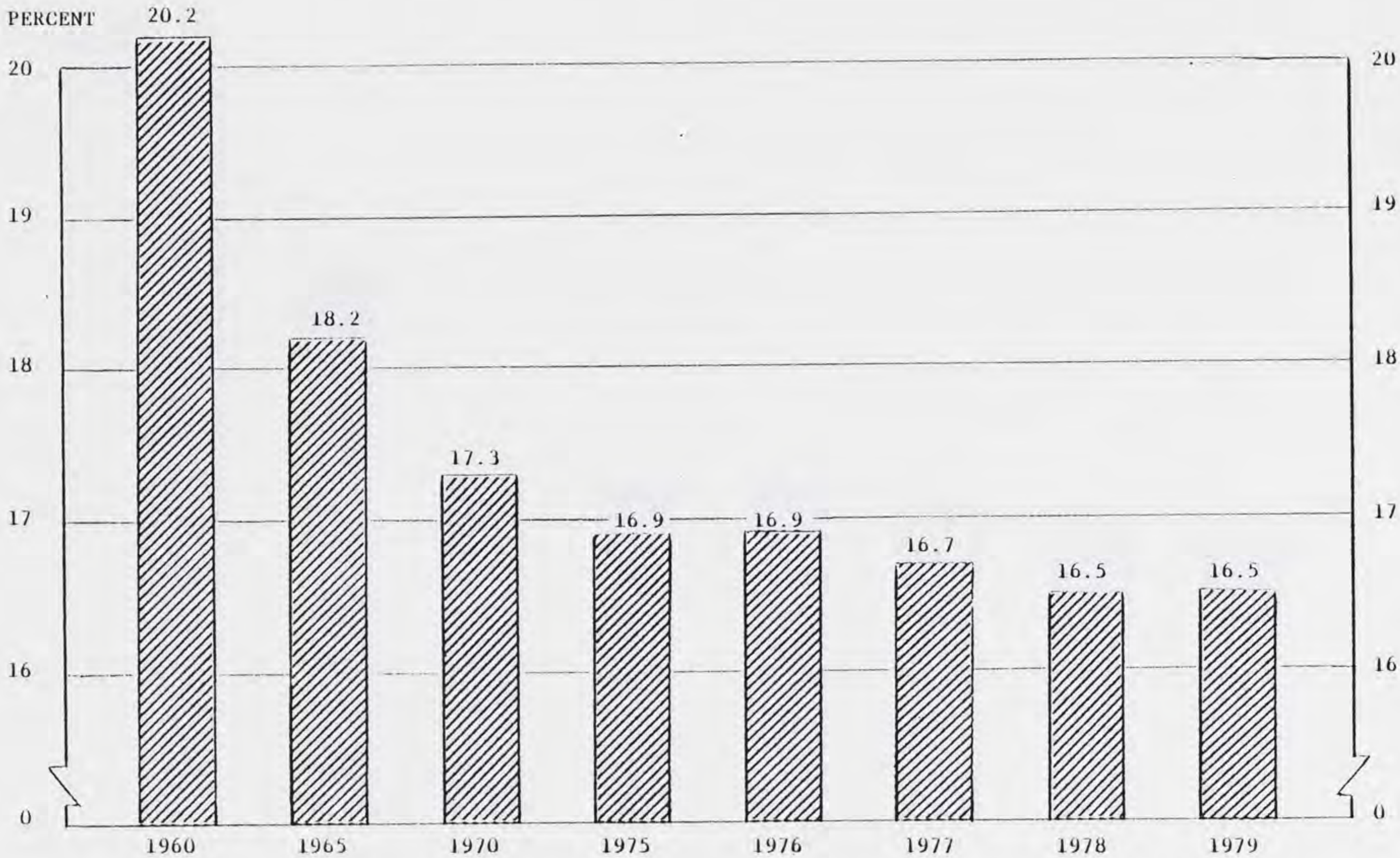

FIGURE 1. PROPORTION OF DISPOSABLE PERSONAL INCOME SPENT ON FOOD IN THE UNITED STATES, 1960-1979

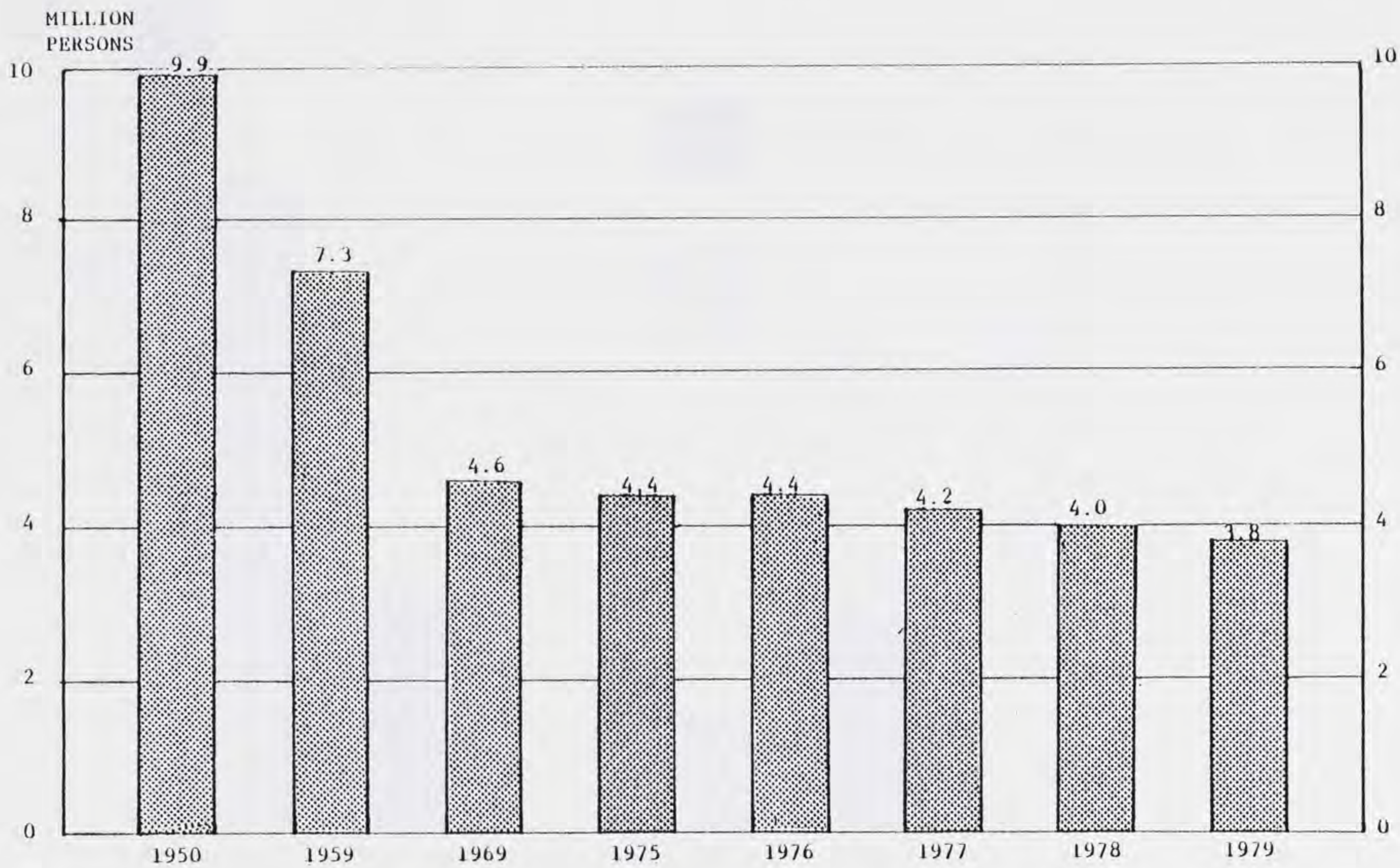

Figure 2. AVERAGE ANNUAL EMPLOYMENT IN AGRICULTURE FOR THE UNITED STATES, 1950-1979

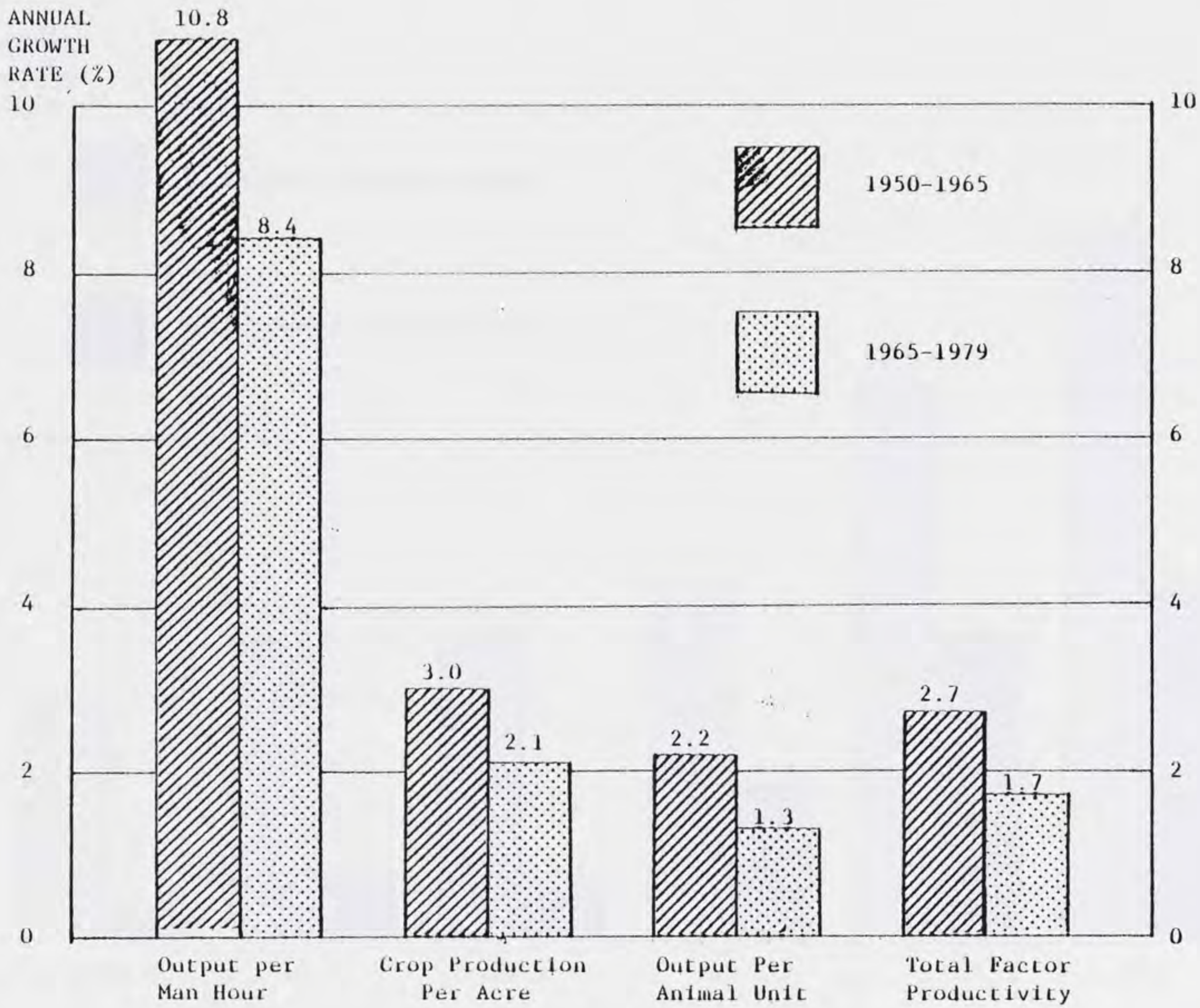

Figure 3 . ANNUAL RATES OF GROWTH (%) IN PRODUCTIVITY OF LABOR, LAND, ANIMALS AND TOTAL FARM INPUTS IN THE UNITED STATES, 1950-65 and 1965-79.

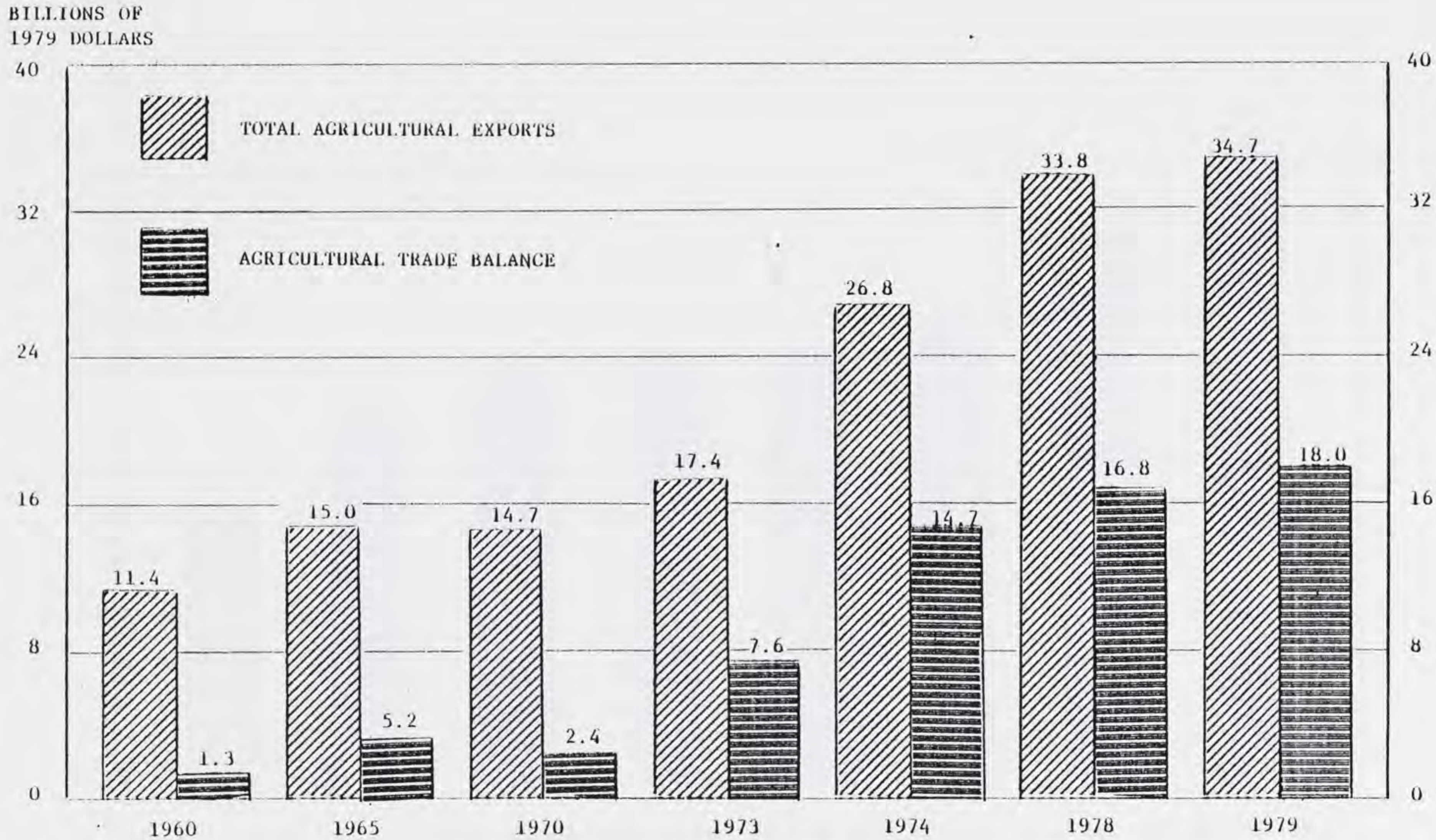

FIGURE 4. AGRICULTURAL EXPORTS AND TRADE BALANCE FOR THE UNITED STATES, 1960-1979

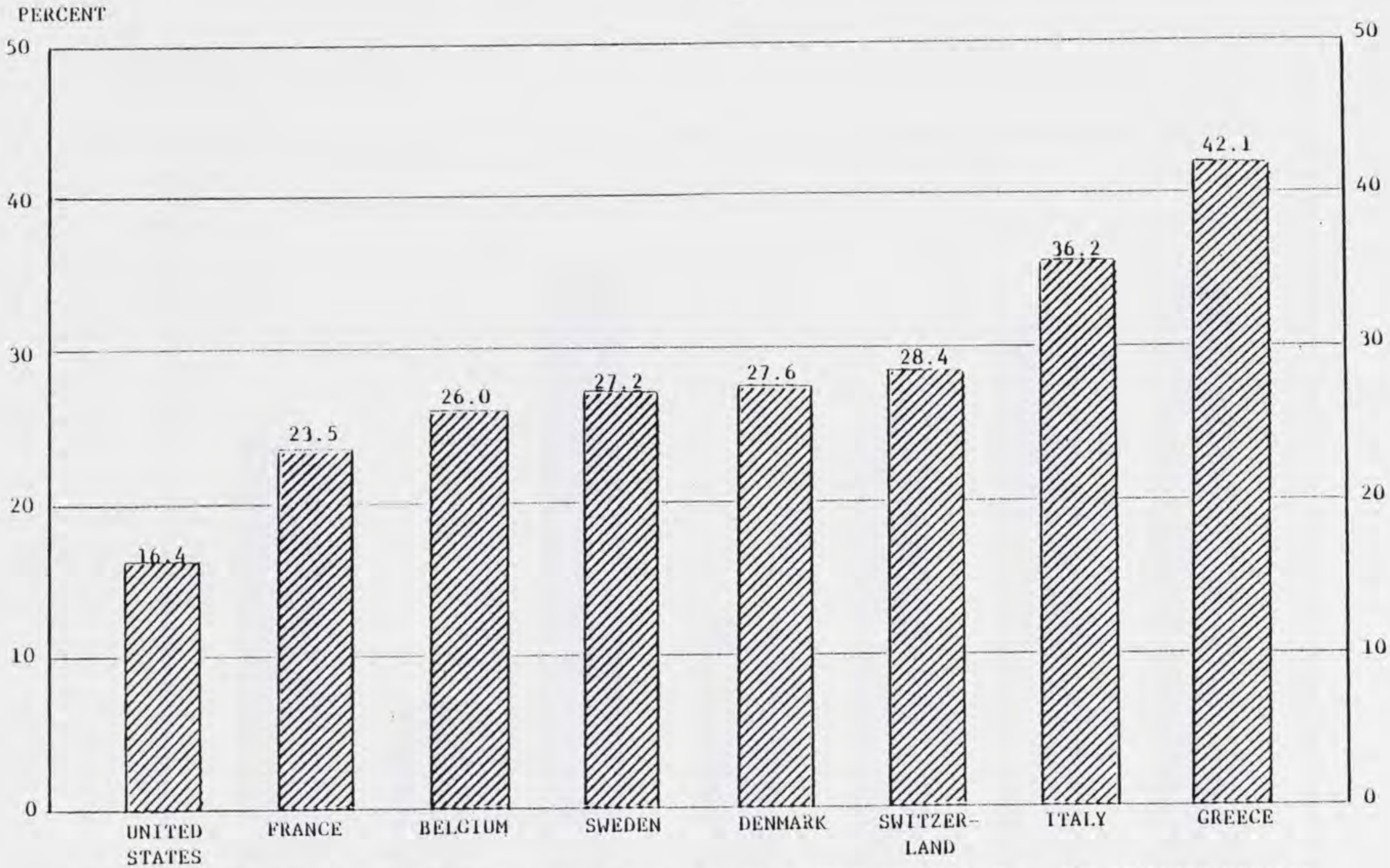

FIGURE 5. SHARE (%) OF PRIVATE CONSUMPTION EXPENDITURES ON FOOD IN 1977, U.S. AND SELECTED WESTERN EUROPEAN COUNTRIES.

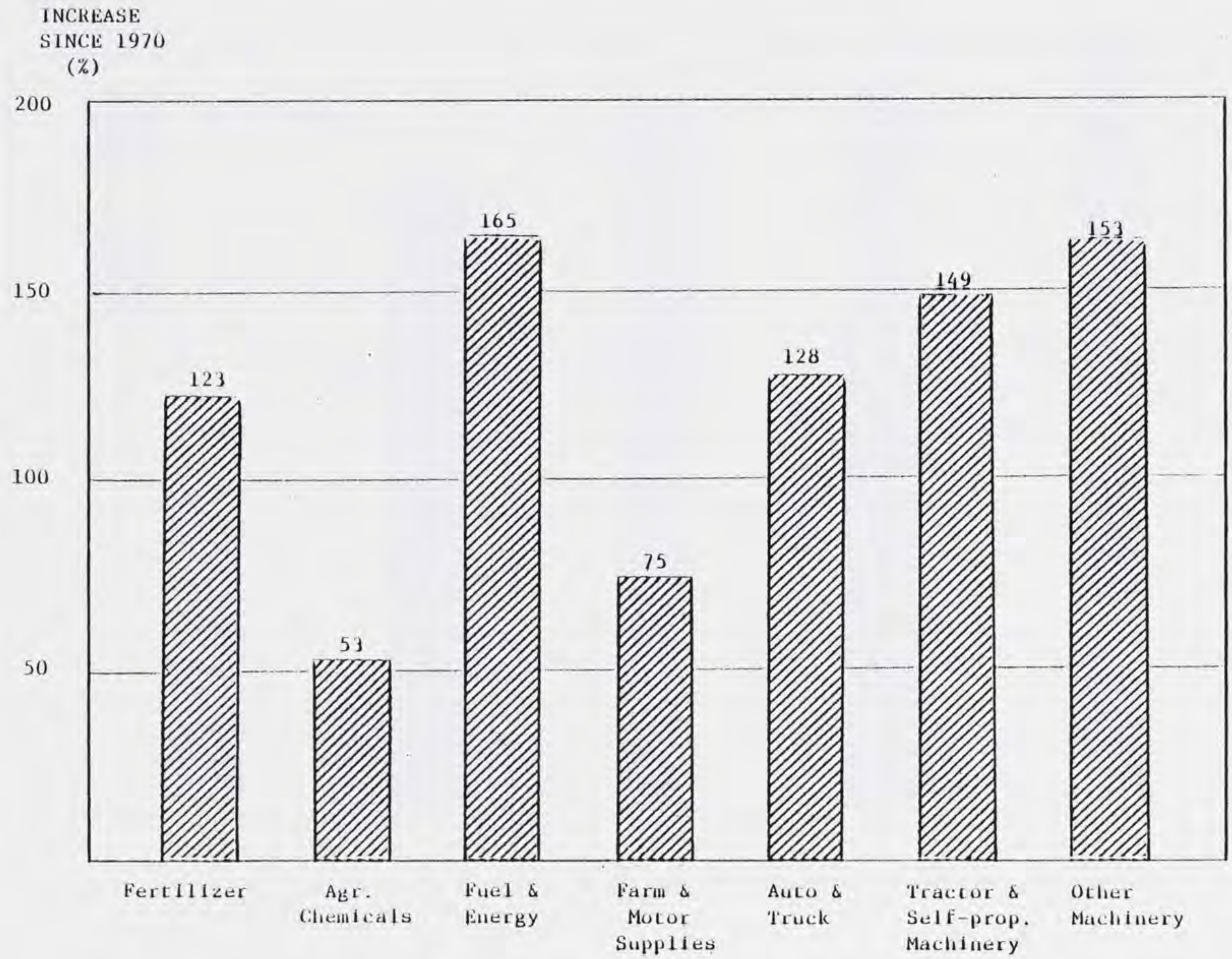

Figure 6. INCREASES IN PRICES PAID BY U.S. FARMERS FOR ENERGY INTENSIVE INPUTS, 1970-1979.

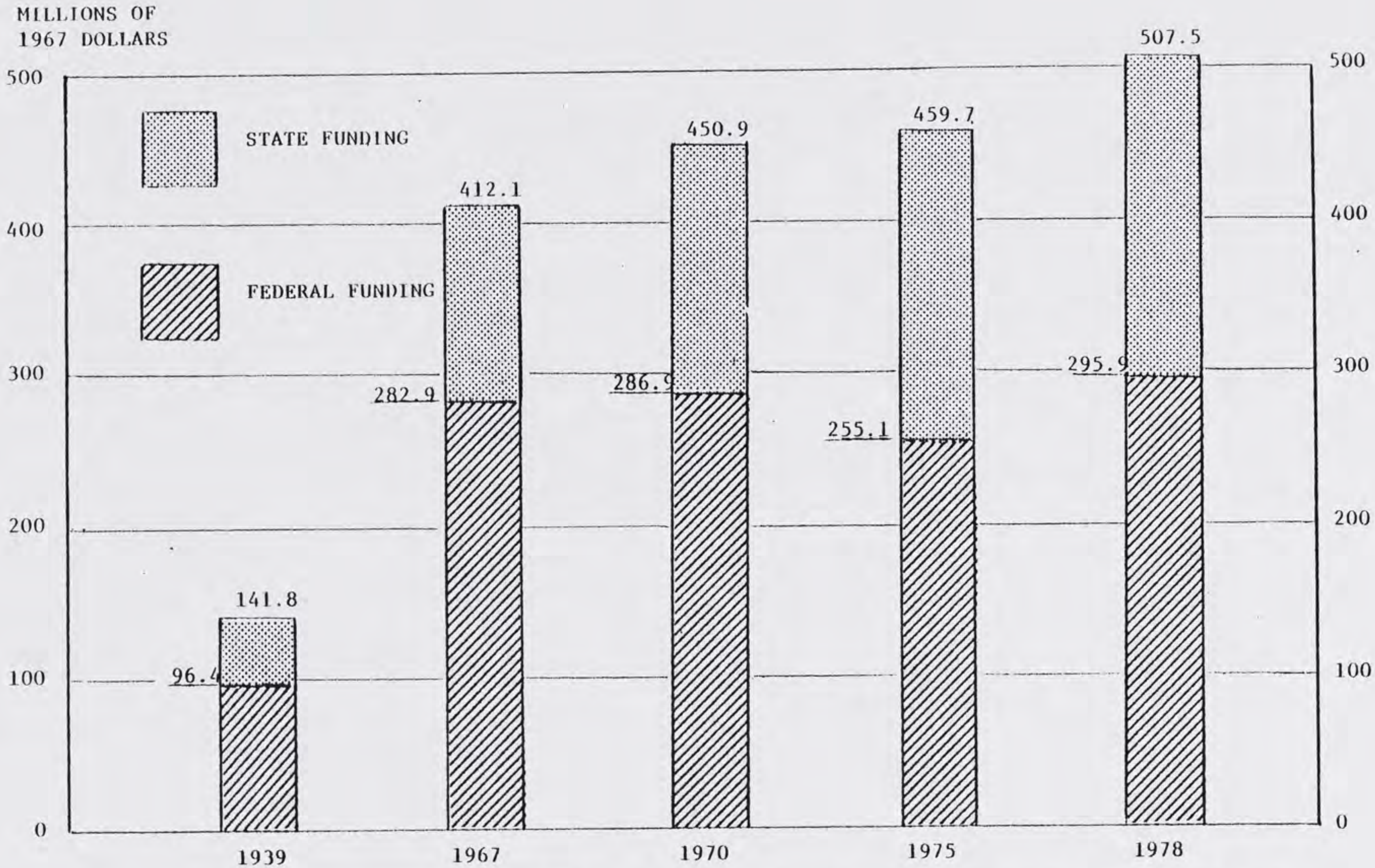

FIGURE 7. TOTAL PUBLIC FUNDING FROM STATE AND FEDERAL SOURCES FOR AGRICULTURAL RESEARCH IN THE UNITED STATES, 1939-1978.