Chapter 4

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

Contents

List of Tables

List of Figure

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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

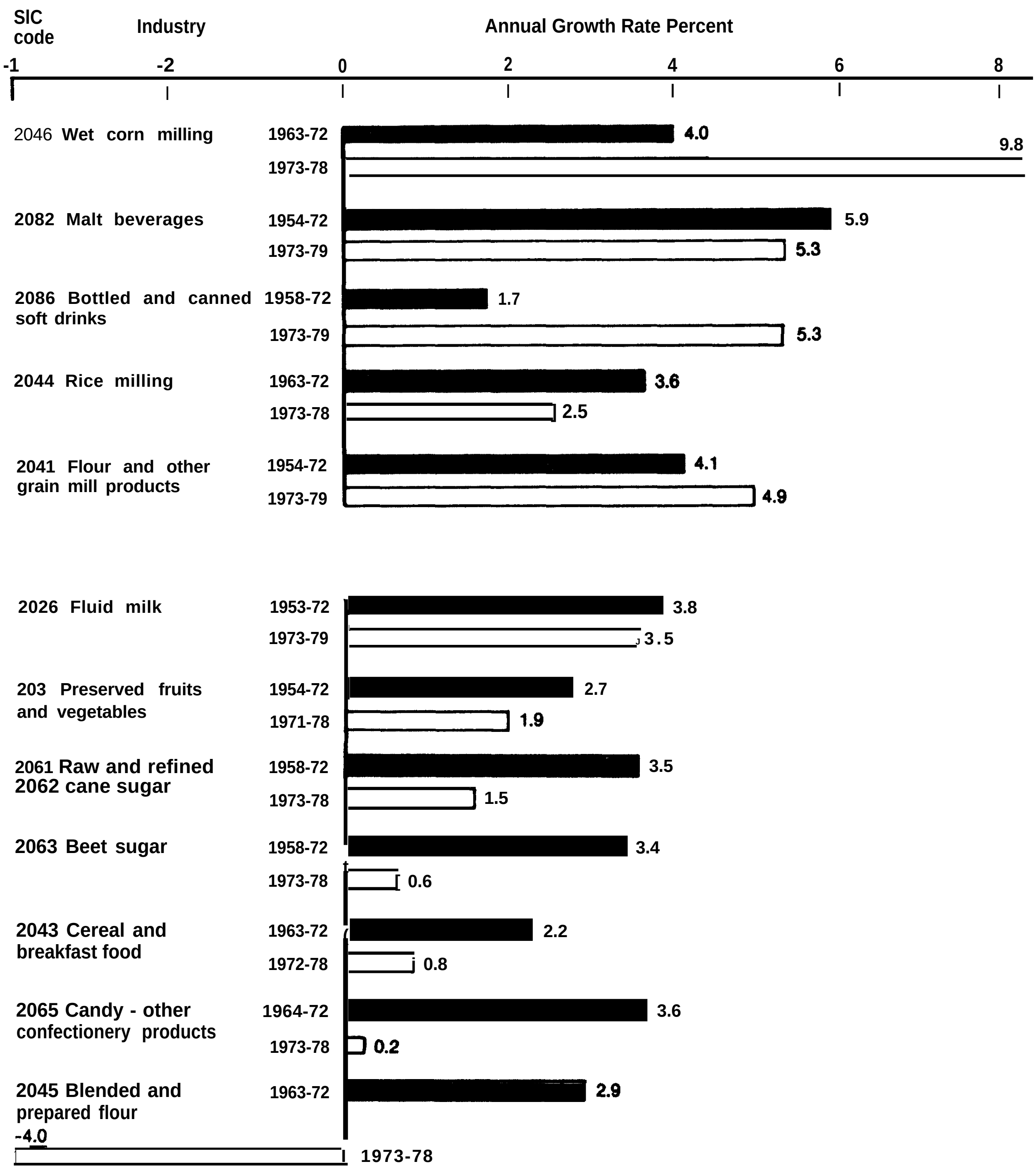
An estimated 70 percent of food costs to consumers is attributable to assembling, processing, transporting, and distributing food; the remaining 30 percent goes to farmers and their suppliers (see also ch. 2). Furthermore, rising marketing costs are the main cause of rising food costs. By leading to 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

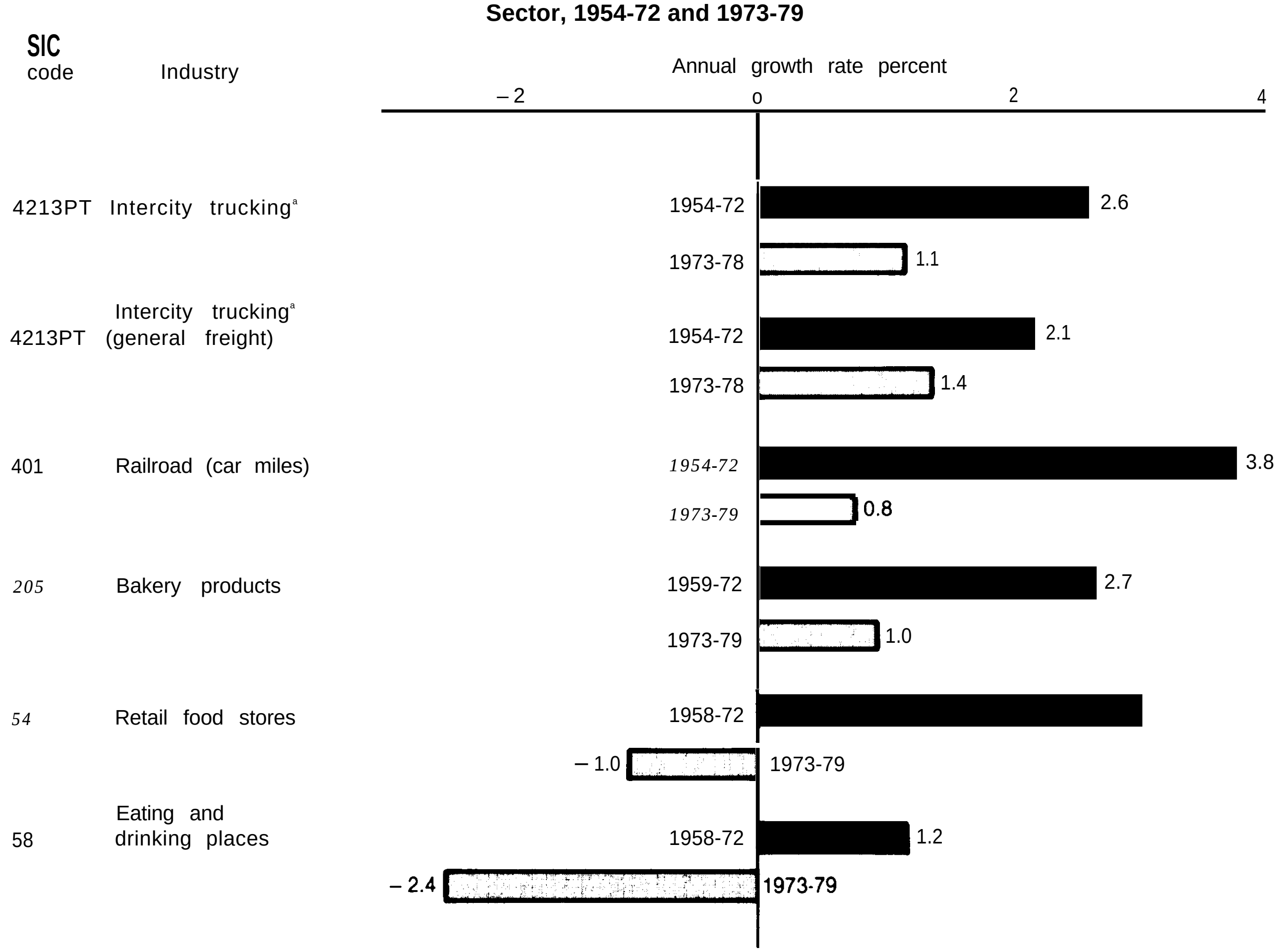


SOURCE Bureau of Labor Statistics, *Productivity Indexes for Selected Industries,* 1979 Edition, Bul. No. 2054, December 1979 [Tiegen, 1981] breakfast foods, beet sugar, and candy manufacturing, labor productivity remained almost constant and the blended flour industry declined at an annual **rate of 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

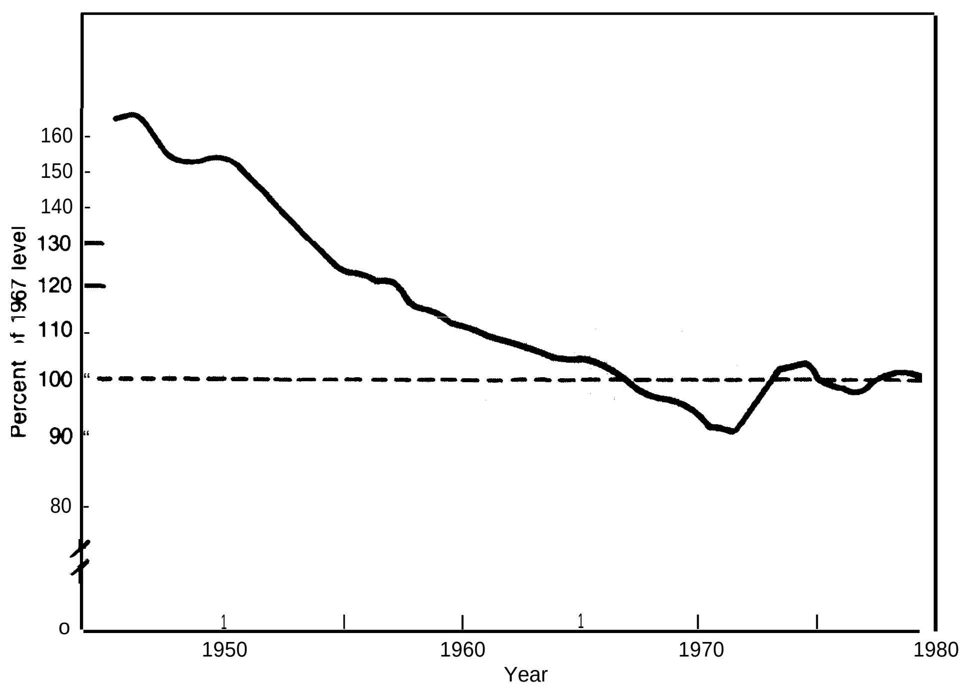
Many food products are wasted because of improper methods of processing and preservation. In some cases, a particular treatment can make food products available that would otherwise be wasted. Research to develop treatments that would be economically feasible to use is currently being conducted (33). 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 resultin[g] 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:

$$TB_c = \tfrac{1}{2} \times MVP_R \times RE \times D$$

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		Ratio of spillovers to regional benefits	Actual ratio of Federal to State R&E expenditures[b] 1949-72
	Inside the region	Outside the region		
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.

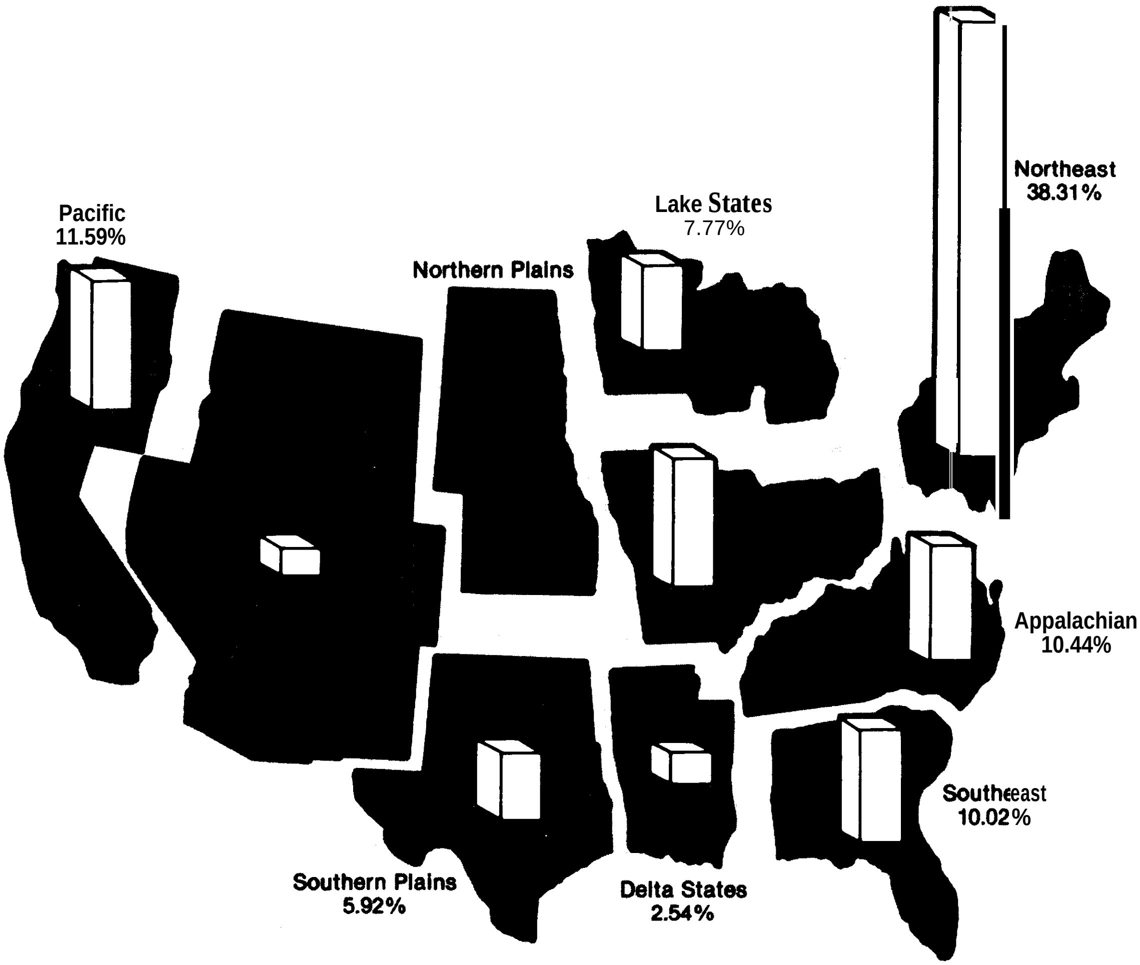
Even though specific data for PHTME research is not available, it could again be inferred with confidence that a similar analysis would result in the same conclusion given the above rationale. For example, the development of a food processing technology which lengthens the shelf life of a food product 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.

● 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)*.

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,

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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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