16

Public Policy in Research, Education and Development

NUMEROUS PUBLIC POLICIES of the United States can best be termed developmental policies. They qualify thus in the sense that they have a basic effect in causing the commodity supply function to shift to the right and to become more elastic through effective (1) reduction of resource prices or (2) increase in the transformation rate of resources into products.[1] In review, the major developmental policies under this definition have been: land settlement policies keeping the price of land low; credit policy reducing the price of borrowed funds; payments and assistance, classified for conservation goals, lowering the cost of materials and technical advice for inputs which increase contemporary output as well as that of the future; reclamation, irrigation and related investments lowering the price of improved land to farmers; research and education lowering the real cost of knowledge to farmers and providing base for increasing the rate of transformation of resources into products. Other developmental policies could be mentioned, or compensation policies which had a by-product effect of increasing output could be cited, but this list includes the major policy elements.

The single most effective one of these policy elements leading to technical and economic development of agriculture over the first half of the 1900's was public policy of research and education in the technology

[1] In contrast, support prices aimed at compensation generally increase output along a given supply function. For example, reduction of P_x in equation (4.26) causes the entire function to shift to the right, with ouput increasing against a given level of commodity price. In contrast, increase of P causes output to increase along a given supply schedule.

and organization of farming. In the last half of the 1800's, progress and rightward shift of the supply schedule probably came more from capital formation and extension of conventional inputs, than from technical advance. But in the first half of the 1900's, the major change came clearly from new technical knowledge and favorable price of this knowledge and the capital items serving to express it. Both are important: Without knowledge of new technique, lowness of price for material representing it is meaningless. With knowledge but with the price of the material so high that it cannot be used profitably, new technical knowledge would be ineffective in altering supply or output structure.

Public investment in research and education to develop and communicate new technical knowledge was a bold step in public policy. It was public action not since duplicated for other economic sectors. In other sectors, industries and firms are expected to, and expect to, conduct their own research. The public would, in fact, find itself confronted with vigorous resistance if it offered or began to conduct large-scale research in drugs, automobiles, television and similar products, with all findings quickly made public ahead of production scheduling and free to all possible producers and consumers.

Ordinarily, major research is carried on in the private sector, firms investing in and producing their own technical knowledge which they sell embodied in new and differentiated products. Research has come to receive an important allocation of resources and investment by large nonfarm firms and industries. They expect to produce knowledge and to realize a return on it. Encouragement of the process is left up to the free market and the play of prices. (See discussion of equations (4.21) and (4.22) in the differential role of prices in allocating research by private firms and public institutions.)

Decision of the American public to socialize research and knowledge for agriculture was a long policy departure from an activity generally left up to the market and private sector. The public implemented this policy by making appropriations to finance it; building institutions to produce and retail it; and hiring deans and other administrators to guide it, as well as other staff workers, as employees of the public. Without public intervention in the market to finance and produce research, the private sector would have found it more profitable to do so and would have increased investments along this line.

In some nations, it is indicated that while agriculture has made important contributions to national economic growth, new technical developments came particularly from private firms.[2] New technologies would have developed in the U.S. without socialization of agricultural research and education, but the process would have been much slower and the contribution of agriculture to national economic growth would have been less. (See Chapter 4 in respect to the real cost of technical knowledge to

[2] Bruce Johnson (*Agriculture's Development and Economic Transformation: Japan, Taiwan and Denmark*, Stanford, 1960, Mimeo., p. 110) uses Denmark as such a country, indicating that major effort in developing improved seeds came from the private sector.

producers and conditions favorable to its supply by the private sector.)

American society has thus been an active participant in economic development of agriculture even in recent decades. The amount it has been willing to invest in agricultural research has grown rapidly, as indicated in Table 16.1. Aside from the ownership of resources in farming, no other nation has had a more direct and effective participation of the public sector in technical development and progress of agriculture. Development of agriculture has not been left to the free market. General society has invested heavily, and reaped high returns, from its direct intervention in promoting progress in the industry. It has had purposeful and well-administered public facilities for doing so. These facilities are represented by the agricultural colleges of the land-grant universities, and the corresponding activities of the U.S. Department of Agriculture. Like post offices, they are socialized services and facilities. In contrast to the post office system, however, where firms and consumers pay some price for the services used, the supply of services from the agricultural colleges is largely unrelated to the pricing and market system. The services to be produced, the funds to be used and the distribution of the product are determined by administrators who are public employees and by legislators who are public representatives. The creation and distribution of the services of the agricultural colleges respond only remotely to the pricing mechanism, and no more so than do the public sector products represented by other governmental services. It is therefore appropriate that the products of the agricultural colleges be analyzed and given direction in terms of the national purposes which are paramount in our society and for agriculture. Certainly the agricultural colleges have been, and are, an extremely important element of public policy relative to the industry. This has been especially true since 1920.

TABLE 16.1

PUBLIC INPUTS IN AGRICULTURAL RESEARCH AND EDUCATION, 1910-59, IN CURRENT DOLLARS (MILLIONS)

Year	Agricultural Research	Agricultural Extension	Vocational Agriculture
1910	6.5	—	—
1915	11.1	3.6	—
1920	14.5	14.7	2.4
1925	18.9	19.3	6.1
1930	31.6	24.3	8.7
1935	25.2	20.4	8.9
1940	41.3	33.1	17.0
1945	47.6	38.1	19.2
1950	104.3	74.6	38.5
1955	144.3	100.7	53.7
1959	225.4	136.0	66.7

Source: USDA and U.S. Department of Health, Education and Welfare.

Upsurge in Productivity

The tremendous upsurge in farm output and productivity of agricultural resources has come since 1940 as reviewed in Figure 16.1. Some of the major innovations relating to this large productivity increase were mentioned in Chapter 14. Other forces leading in this direction also should be mentioned. A large amount of new technology was accumulated during the 1930's depression when farmers lacked the capital to innovate and the factor/product price ratio was less favorable for these purposes than in later decades (although some important innovations did take place in the 1930's, with a more complete spread during the 1940's). But also, we should mention the larger investment and greater effectiveness of research and education following this period. Between 1914 and 1934, the agricultural extension service had been in operation less than 25 years. After that time, it began working with a "new generation" of farmers, a great number of these now being graduates of 4-H clubs and vocational agricultural education. Too, the extension services were themselves coming to maturity and had both better-trained persons and more effective methods in the decades following 1934. Much of the same also can be said about agricultural research, with important innovations, discoveries and adaptations coming out at increased rate following the depression.

Finally, we must mention the "stage of economic development" and the drawing of more private firms into research, communication and input processing. They could make investments leading to more rapid and homogeneous improvements. Starting in the 1930's, a "vast movement" took place, with input fabrication moving from farm firms to nonfarm firms. Common examples were power units, hybrid corn, fertilizer nutrients and similar innovations. As Figures 16.1 and 16.2 illustrate, the great upsurge in farm output and resource productivity parallels the steep rise in "other" inputs than land (real estate) and labor. The "other" inputs included especially materials representing new forms of capital uncovered by research. Few forms of nonland and nonlabor resources in use in 1960 were the same as those in use in 1930. (It might be argued that inputs such as livestock and feed grains are the same forms of inputs. However, the breeding stock and seeds used in producing livestock and feed grains were quite different inputs than in 1930.) With this large growth in capital inputs, private firms could dominate the supply of resources to agriculture. The quality and productivity of farm resources then could be increased more rapidly and effectively.

Given alone economic development and further commercialization of agriculture, growth in productivity rate of farm resources is not likely to slacken. Any slowing of growth in productivity rate is more likely to come from the biological limits of natural resources or endowments as capital inputs are increased against them. But as pointed out in Chapter 2, this biological restraint does not promise to restrict growth in farm output and resource productivity over the 1960's.

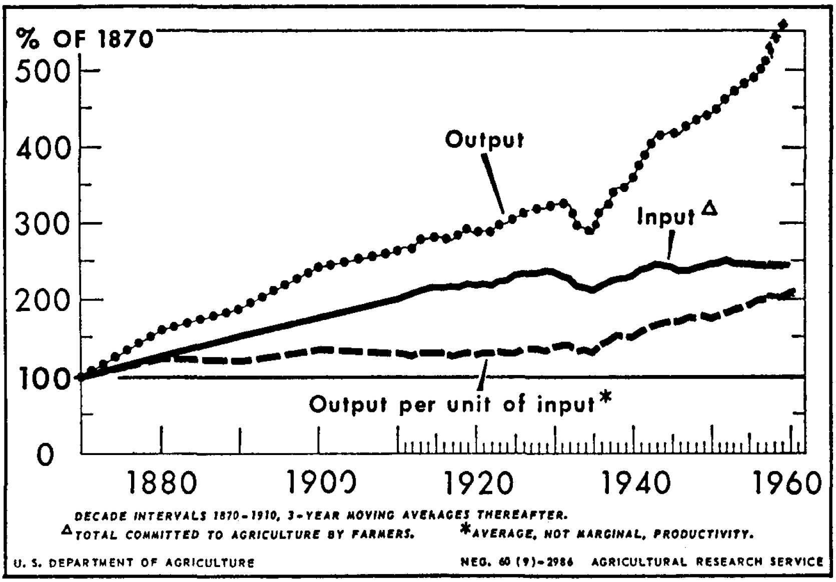

Fig. 16.1. Changes in Output, Input and Factor Productivity. U.S. 1870–1960.

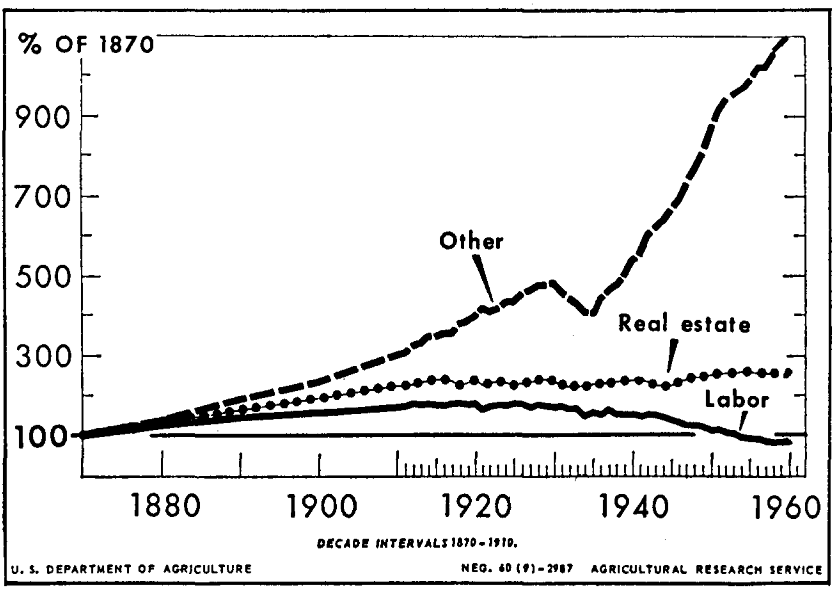

Fig. 16.2. Changes in Major Input Groups of Agriculture. U.S. 1870–1960.

RETURN FROM PUBLIC RESEARCH AND EDUCATION

Public research and educational institutions for agriculture have been generally well administered. With few exceptions they have had dedicated persons to guide them and they have been relatively free from political obstacles restraining them from their realized goals.[3] Their success in promoting the development of agriculture is now legend, not only in the United States but the world over. Other nations look to the system and wish that they could duplicate its developmental attributes. Given its conscious objectives, perhaps there have never been more efficient public institutions and investments, or at most very few. Farm output has more than doubled since 1910, but with nearly a halving of the farm labor force. Labor productivity in agriculture increased around 300 percent from 1910 to 1960. We are rapidly approaching the time when only 5 percent of the labor force is needed to produce the nation's food product, plus provision of some for export. Counting all farms and farmers, each worker in agriculture produces food for about 30 other persons; but considering only true commercial farmers who produce the very major part of output, the figure is more nearly 50 persons fed per farm worker—even allowing some exports. A nation can be wealthy only if a small amount of its labor force is required for food. In fact, the elementary step in economic progress is in developments which allow transfer from fields to factories and commerce. Per capita wealth and economic progress is extremely restrained in countries where 75 percent of the labor force is engaged in agriculture, such as in India or even greatly so where 40 percent of the labor force is so required, as in Russia.

The return to U.S. society on investment in public research and education to promote technical knowledge in agriculture has indeed been large. The payoff is not easily measured, starting from initiation of this investment. Difficulty arises in measurement because of problems in aggregation of commodities serving as inputs and outputs; in identifying research inputs and their outputs in both the private and public sectors; in evaluating knowledge which would have been "self generating" within the farm industry apart from public activity; and in others. But while there can be questions about the exact and specific level of return, there is no doubt that it has been extremely high. While the measurements serve as approximations and can give rise to technical questions of measurement, the data of Table 16.2 suggest some general levels of return. Over 50 years, output increased by nearly 110 percent with an estimated increase of only 22 percent in value of inputs, excluding taxes. The increase in annual capital was only slightly more than the decrease in value of labor. If the value of input per unit of output, considering output to be the same aggregate, had been the same in 1959 as in 1910, about $42 billion in total inputs would have been required at 1947–49 prices. Hence, we might consider the saving, comparing 1959 to 1910, to be the

[3] For notes on the politics of land-grant colleges, see C. M. Hardin, *The Politics of Agriculture*, The Free Press, Glencoe, Ill., 1952, Chap. 2.

TABLE 16.2

INDICES AND ACTUAL OUTPUT AND INPUTS OF AMERICAN AGRICULTURE FOR SELECTED YEARS, 1910–59, WITH VALUE OF INPUTS SAVED AT 1947–49 PRICE LEVEL (1910=100)

Year	Output Index 1910=100	Input Index 1910=100*	Actual Inputs Used at 1947–49 Prices†	Inputs Required at 1910 Productivity Rates (1947–49 Prices)†	Inputs "Saved," Actual Minus Required‡
1910.......	100	100	20.1	20.1	0
1915.......	111	106	21.3	22.4	1,032
1920.......	115	113	22.8	23.2	375
1925.......	115	114	22.9	23.1	281
1930.......	118	115	23.2	23.8	559
1935.......	118	104	21.0	23.8	2,734
1940.......	139	116	23.3	27.0	3,710
1945.......	156	119	23.9	31.4	7,507
1950.......	166	120	24.1	33.1	9,295
1955.......	185	121	24.3	37.3	12,992
1959.......	207	122	24.4	41.7	17,266
1910–59 Mean....	—	—	22.9	24.5	4,586

Source: Based on USDA data. (See Loomis and Barton, *loc. cit.*) Indices vary slightly from those in other tables and charts because of base of computations.

* Index of inputs excluding taxes and differs slightly from indices of inputs in other chapters where taxes are included.

† Billion dollars at 1947–49 prices.

‡ Million dollars at 1947–49 prices.

difference between this projected figure and the actual estimate for 1959. On this basis, the 1959 saving in resource inputs is approximately $17,266 million.

We cannot derive a lagged or dynamic model to relate research and educational investment in one period with its product in a later period. Data show a $225 million (current dollar) expenditure (Table 16.1) by the public sector for agricultural research in 1959. The expenditure by the private sector for agricultural research was about $240 million (current dollars) in the same year.[4] The average savings per annum in inputs, as computed in Table 16.2 were $4,586 million over the 50-year period 1910–59 at 1947–49 prices.[5] Using 1947–49 prices, the total public expenditure on agricultural research over this same period was $2,953 million. The corresponding public expenditures for education were $2,158 for extension, $982 million for vocational agriculture and $52 million for agricultural colleges. Figured as return on public investment in agricultural research alone, the average annual input savings in Table 16.2 represent a return of 155 percent on the total research expenditures over the period

[4] R. L. Mighell (*American Agriculture*, Wiley and Sons, New York, 1955, p. 130) places the figure at $140 million in 1953.

[5] Loomis and Barton (*Productivity of Agriculture*, USDA Tech. Bul. 1238) estimate the resource savings in 1957, comparing this year only against productivity gains of 1940, to be $9.6 billion. Comparing 1957 with productivity gains since 1910, they compute resource savings to be $16.3 billion when adjustment is made for purchase of specific items and taxes are included as inputs.

1910–59. If we add all public investment in agricultural education to research, saying that the research had zero productivity until it was communicated, the total public investment (at 1947–49 prices) in research and education, over the period 1910–59, was $4,145 million. The average annual input saving of $4,586 million is a 110 percent return on this total investment. If we estimate private expenditure on agricultural research and education to be a fourth of the public expenditure, the return is still 89 percent, and even 74 percent if we put private expenditure at half of public expenditure over the full 50 year period.

Obviously the return is much higher than these figures. There are several reasons: The expenditures on research are greatest in recent years and input savings or returns are increasing. The returns extend on forever, and those being realized now are from smaller annual inputs at an earlier date. Finally, the assumptions that the aggregate product was the same in 1959 as 1910 also cause savings to be underestimated. The product mix consumed in 1959 was a much more costly one in resources, to obtain the same level of food nutrients, than that of 1910. But even at returns of around 100 percent, or even of 70 percent, the social payoff is large. This is a return far above that of student education cited in Chapters 12 and 13, or the rates of capital return of the more monopolistic industries cited in Chapter 5. If inputs could be accurately measured against lagged productivity, the social return to the public investment, or all investment, in research would indeed be high. This would be especially so for particular innovations. Griliches estimates the return on research for hybrid corn, an extremely important innovation, to be in the neighborhood of 700 percent.[6] Research in general undoubtedly has a return well over 100 percent.[7] (Hybrid corn is one successful venture. Others requiring investment are not always successful; some which are successful have a lower payoff.)

Research, education and communication of new technology has been productive elsewhere in the world also. In Asia, Japan represents a nation of high relative economic development. Given factor supplies and prices which still favor technology resting heavily on labor, it has an agriculture which has high technical and economic efficiency. Smith indicates early interest in and spreading of knowledge in farm technology.[8] He indicates that progress was quite remarkable, during the Tokugawa period, from a combination in spread of technical knowledge, development of transportation and growth of markets. The use of fertilizers spread widely and the number of recorded rice varieties increased from 177 in the seventeenth century to 2,363 by the middle of the nineteenth century. Evidence indicates that there was widespread interest in improved technology and considerable discussion and writing in this respect even by peasants. As part

[6] Zvi Griliches, "Research Costs and Returns: Hybrid Corn," *Jour. Polit. Econ.*, Vol. 46.

[7] It is estimated that national rate of return on all research and development is 100 to 200 percent. See R. H. Ewell, "Role of Research in Economic Growth," *Chem. & Engr. News*, Vol. 33.

[8] T. C. Smith, *The Agrarian Origins of Japan*, Stanford University Press, Stanford, Calif., 1959, Chap. 7.

of this development, it is indicated that between the late sixteenth and seventeenth centuries, 398 new villages were founded in Musashi Providence, irrigation and double cropping were developed and rice output rose from 667,000 koku to 1,167,000. Johnson and Mellor report that per annum increase in food output in Japan was 2 percent between the decades of the 1880's and 1911–20, on a land area already fully settled, and labor productivity doubled.[9] They also report that the expenditures for agricultural research, extension-type activities and other "developmental" sources were of strategic importance in both Japan and Taiwan, with the productivity of agricultural labor for the latter increasing by 130 to 160 percent over a 30-year span and a threefold increase in sugar yields between 1901–10 and the 1930's. Kazushi's data indicate that real income produced in Japanese agriculture doubled between 1881–90 and 1911–20 while labor employed in agriculture declined by 10 percent.[10] Johnson indicates that in the 30 years, 1881–90 and 1911–20, Japan increased agricultural productivity by 77 percent, with an increase of only 21 percent in area under cultivation and an increase of 46 percent in yields.[11] Population increased by only 44 percent during this period and farm labor force fell by 14 percent.

Japan is a country where increase in agricultural productivity contributed greatly in capital transfer to nonfarm industry, as well as to rapid rise in food output and farming efficiency. The increase in agricultural output came with modest government investment in research and education, but an investment considered to be crucial.[12] Increase in capital inputs was very modest, or even small, against the increase in farm output and productivity of land and labor. The increase in product of agriculture provided a surplus for transfer to the nonfarm sector, in providing capital for economic progress. This process in Japan was indeed the equal of that in the United States.

We have ample evidence, then, that public investment in knowledge for agriculture and in knowledge of people in agriculture can bear high payoff, both in aid to general economic development and in value of resources to produce agricultural output at demand level. The United States provides evidence in the Western world and Japan in the Eastern world, both being in the vanguard of development over the last century for their general regions. Both illustrate a large increase in output without a corresponding increase in inputs, measured in most any manner. Abramovitz and Kendrick show similarly for the U.S. economy that only about one-third of the output increase between 1899 and 1953 can be

---

[9] B. F. Johnson and J. W. Mellor, "Contributions to Economic Growth," *Food Research Institute Studies*, Vol. 1.

[10] Ohkawa Kazushi, *Economic Growth and Agriculture*, Annals of Hitotsubashi Academy, 1956.

[11] Bruce Johnson, "Agricultural Productivity and Agricultural Development in Japan," *Jour. Polit. Econ.*, Vol. 34.

[12] Smith, *loc. cit.*, and Johnson and Mellor, *loc. cit.*

attributed to increase in input of land, labor and capital as conventionally defined and in physical measurement.[13]

The difference between growth in output and conventional inputs for American agriculture is even greater over recent decades. We have explained in Chapter 11 how exposition of knowledge of new inputs or their productivity effects and of their relative prices can lead to output increase which is more than proportional to value of inputs. Together it is improvement in general knowledge, as reflected in the forms, quality and productivity of capital and human effort, which allows progress in this sense. The public investment in research and education for agriculture had indeed been efficient and of high payoff for the American society of consumers. It remains so, and prospects are that it can provide further high return in the future. Society would have difficulty finding many investment opportunities in either the public or private sector, which had greater promise of return to consumers in general, than this activity which has been embraced as an active public policy. In terms of society returns, it is a public activity to be continued and expanded, until such time that it can be proven that sufficient other investments provide opportunity of such high, or higher, returns.

Input and Productivity Changes

Not all of the increase in output in recent decades can be attributed to technological change or improvement in resource productivity. Over early periods in the economic development of U.S. agriculture, greater supply of farm products was attributed mainly to increased input of resources. More land, labor and capital were used in extending the magnitude of the farm industry and its output. Even as late as the period 1870–1920, a greater portion of increase in farm production came from increased input of resources than from an increased productivity of the conventional resources measured in the aggregate and classical manner of land, capital and labor. However, as is suggested in Table 16.3, the portion of output imputable to productivity increases is much greater than that for input increases since 1920. Increase in output from productivity change is estimated to exceed by five times the output increase due to input change in the period 1920–39. The increase in output between 1950 and 1956 is estimated to come entirely from productivity changes, with the total value of inputs decreasing by 9 percent as a large amount of labor migrated from farmers and was not offset by a larger increase in capital items. Even for the period 1911–56, output increase attributable to technological improvement or productivity change is estimated to be double the increase in output attributable to increase in aggregate value of the inputs.

---

[13] M. Abramovitz, "Resource and Output Trends in the United States Since 1870," *Amer. Econ. Rev.*, Vol. 46; J. W. Kendrick, *Productivity Trends in the U.S.*, Basic Tables, Mimeo.; M. Brown and J. A. Popkin, *Measure of Technical Change and Increasing Returns to Scale*, University of Pennsylvania, 1961, Mimeo.

TABLE 16.3

CHANGE IN OUTPUT ATTRIBUTABLE TO INPUTS AND PRODUCTIVITY CHANGES AND AVERAGE RATES OF CHANGE IN OUTPUT, INPUTS AND PRODUCTIVITY FOR SELECTED PERIODS

	Percent of Output Change Attributable to:		Average Annual Rate (Percent) of Change in:		
Period	Inputs	Productivity	Output	Inputs	Productivity
1870–1911......	72	28	2.45	1.77	.67
1911–1920......	129	−29	.70	.89	−.19
1920–1939......	16	84	1.08	.17	.91
1939–1945......	34	66	3.05	1.04	1.99
1945–1950......	49	51	.81	.40	.41
1950–1956......	−9	109	1.89	−.17	2.06
1939–1956......	22	78	1.98	.42	1.55
1911–1956......	31	69	1.34	.41	.93
1870–1956......	56	44	1.86	1.05	.80

Source: Loomis and Barton, *op. cit.*, p. 9. Indices used above are based on 1947–49 = 100 with inputs valued on a constant dollar basis.

Technological improvement is the main phenomenon represented in productivity increases and is reflected in the manner explained in several earlier chapters. Or we might say that the main effect of public investment, or the public sector, in economic development of agriculture is in output increases attributable to increased productivity of resources measured in their aggregate and classical form as land, labor and capital. On the other hand, the major effect of the private sector is in increased factor input, especially in new capital forms, although the private sector also contributes importantly to productivity change in the research and knowledge it develops and in the more productive forms of capital which it markets in agriculture.

Without the new forms of capital representing technical change, output would be forthcoming only as inputs are extended for a given production function. Marginal and average productivity of resources would then decline. Agricultural expansion was readily possible as the nation was first settled and land, labor and capital could be increased largely in "true scale manner." After the public domain was fully settled, however, capital and labor were increased against a relatively fixed area or input of land. As expected for such a period when inputs are largely retained in conventional technical form, Loomis and Barton's figures show the average per unit productivity of resources to have declined in the period 1911–20. However, with momentum built up in agricultural research thereafter, productivity per unit of aggregate resource, with resources measured in the classical manner, increased rapidly. Increase in resource productivity has dominated increased resource inputs, in causing output to increase (i.e., the portion of output attributable to the two sources) since 1920. The very large increase in productivity came with the shift from horse to tractor power and the diversion of land from feed for the former feed for livestock; with the introduction of hybrid corn, other new seeds and summer fallow; with the widespread use of fertilizer over much more of the nation; and with other important chemical, biological and mechanical innovations.

The public has not produced the inputs which have been physically transformed into output as the product supply of agriculture has been increased. It has, however, been the dominant factor in developing the concepts, forms and ideas of these innovations and in predicting their productivity effects. Once their forms and productivity effects have been predicted to be favorable, private firms then have been able to produce these inputs leading to increased productivity, and the final change in rapid economic development of agriculture under a fixed land area has been attained.

FOOD AND CONSUMER POLICY

At its outset, public investment in agricultural research had basic reason for being classified as *policy for agriculture.* It is now best termed as *policy for consumers.* Land supply had, in initiation of public research institutes for agriculture, been fairly well exploited, and opportunity to increase aggregate farm income through extension of land inputs at favorable price had largely disappeared.[14] The opportunity then existed for developing new forms of capital resources and raising the productivity coefficients of conventional resources remaining in use. As mentioned previously, the effect also was that of producing knowledge as a resource, with the public subsidizing its costs, through the actual process of producing it, and keeping its real price low to farmers. In this pricing effect, the relevant relationships led to an extension in output of agriculture and a rapid shift in the supply function (as suggested by a relative reduction in P_x in equation (11.9) or an increase in the elasticity or multiplier in equation (11.7).

But increase in the supply function and rapid increase in output also promised increased farm income under demand regime of higher elasticities in respect to price and income. Assuming that the demand regime allowed increased output to bring forth greater aggregate revenue and increased net income, public investment in agricultural technology represented policy element with a major gain to agriculture. This is exactly what it was expected to do. Under this demand regime, aggregate welfare increase was generally assured in the national community or society of consumers and farm producers (although certainly, there were specific groups which might have realized greater gains from restrained supply function and greater price of commodities and resources). Also under this demand regime, existing in an extent not easily specified, gain could be twofold, with distribution of benefit broadly to consumers and farm producers. Given a high rate of demand expansion, from immigration and high birth rate plus growth in income when this elasticity facet provided more growth opportunity than at present, the real price of food could be restrained and lowered; at the same time, revenue of farm output could

[14] For a previous analysis of public policy in these respects see Earl O. Heady, "Public Purpose in Research and Education," *Jour. Farm Econ.*, Vol. 45.

increase in the relative magnitudes explained in Chapters 1 and 3. Positive-sum outcomes in real income gain were thus more evident as between farm producers as a group and consumers. Gradually but certainly, however, the demand regime explained in Chapter 6 came about, with the effects in revenue and resource returns explained in earlier chapters.

With emergence of this stage in economic development and in related structure of supply and demand in farm products, the certainty of positive-sum real income gains, broadly between farm producer group and national consumer group, no longer existed. To be certain, consuming society continued to benefit in large magnitude through decline in the real price of food, and in the extreme abundance and variety of food produced with an approaching minimum of resources for this purpose. These gains to consumers are an important basis for further extension of the food supply function, and its interrelated lessening of the resource demand function in agriculture.

The ongoing consumer gains being realized and those in prospect themselves justify continued public and private investment in research and education on improved food production technology. This will continue true, as long as the return on this social investment is at the high levels set forth earlier, and until it drops much nearer to the levels of other conventional investments in either public or private sector. And should it ever drop to this level, further activity of the public in financing and producing improved food technology would still be justified, both in terms of equality of resource and investment returns and in terms of increasing degree of certainty and "food productive capacity contingency" in a world matrix with yet-to-be-established vectors in population, political and developmental space. One problem in guaranteeing that this public activity be continued at scale commensurate with its high payoff is broader knowledge for administrators of agricultural research and education, indicating the gain to general society and the need to so justify it and claim support for it. Appeal now should be made more to general society than to the farm sector.

The large gain to consumers does not, however, guarantee positive-sum short-run outcome in real income or utility to consumers and farm producers aggregated as a community. Nekby has made an attempt to predict monetary gain to farm producers and consumers from agricultural research.[15] He obtains negative outcome for producers and positive outcome for consumers. But while the estimated monetary gain to consumers exceeds the monetary loss to producers, a similar positive-sum outcome in utility over the two groups is not guaranteed (in the absence of compensation). Large forward press in supply against an inelastic food demand causes decline in revenue of agriculture as explained earlier. Without ability to make interpersonal utility measurements, we cannot be certain that the gains to consumers in lower real price of food (and not services incorporated with foods in the nonfarm sector) out-

[15] A. B. Nekby, *The Structural Development of American Agriculture*, Ph. D. thesis, Iowa State University, 1961.

weigh the loss to farm producers in revenue. Here we speak of sectors of agriculture such as those in feed grains, wheat and cotton where market orders and other supply restraints have not been effective in slowing the pace of supply growth so that an equitable share of progress fruits are retained with producers.

But even if we consider benefits to farm groups which have gained in managed supply to retain progress rewards, or producers of other sectors who have gained in ability to race output ahead of the industry average, we still have the problem of short-run distribution of costs and payoffs from farm economic progress. Gains to these producer groups, as well as to consumers at large, come at income sacrifice to farmers who are not in advantageous position to share in the fruits of this progress. Farm policy from 1930 to 1960 can, as has been mentioned in earlier chapters, be interpreted as recognition of possible negative-sum outcome unless compensation was arranged. Unfortunately, the compensation methods used were somewhat clumsy and costly, relative to alternatives which were available.

Certainly the philosophy of early public investment in agricultural research and education was in terms of *farm policy* and income, gain to consumers being secondary. This was appropriate, with the major part of the households then falling in agriculture. The gain to consumers was a "windfall profit," but one indeed of great magnitude and itself sufficient basis for public action. With the change in demand regime and the stage of economic development explained above, public investment in improved farm technology should now be looked upon as for purpose of *food policy* and major gain to consumers. This itself is important reason for public investment in the process. The accomplishments of improved technology as element of food policy have been great, but too little recognized by both the public and administrators who direct the public facilities which produce knowledge in new farm techniques. The public at large is only slightly aware of these efficient institutions and public investments, in extending food supply and in lowering its real cost. The product and contribution of these institutions is much broader than most staff employees recognize, but it is more to national and consuming society than to farm society per se. Nonfarm society would probably support agricultural colleges more heavily than at the present, and more richly than is now done by the farm population, if they had more complete knowledge of the origin and magnitude of these gains. The empirical evidence for this statement is at hand: Large industrial states with small proportion of population and income from farms often better support their agricultural colleges than agricultural states. In comparison to past decades, if appropriations are related to value of farm marketings, and as measured in relative increase in appropriations for agricultural research since 1920, agricultural research moved somewhat out of the farm states to the city states. This relative shift, now more or less stabilized, does not follow an "exact pattern" and has perhaps favored most those states with "more balanced" income from both industry and agriculture; as well as those with products having greatest demand elasticities.

The role of agricultural research and education in national economic development and food policy needs direct recognition, in relation to further opportunities open to gain by consumers and for general integration and systematization of over-all agricultural policy. In this vein, the agricultural colleges might best change their name to The College of Food and Agriculture. The land-grant colleges and the U.S. Department of Agriculture have performed well. Their creation was visionary, coming at a time when the goals of society were those of agriculture because the population was thus distributed. They now function in a time when the goals of agriculture are largely those of society because communication is so effective, income averages so high and farm people are a sparse portion of the total population. Economic growth caused gradual transition from a time when contribution of public research and education to farm families was dominant to the time when its contribution to consumers became dominant. This desired time path in redirection of gains from technical advance was not consciously planned. However, it was an optimum process, given the restructuring of society which accompanies economic development. It has been true, however, that a parallel restructuring of research and educational programs to mesh with this change has yet come about in only a few institutions. The outcome or product of publicly sponsored farm technical advance over the 1950's undoubtedly has been inconsistent with that believed to prevail by many staff workers in land-grant colleges.

The greatest marginal challenge to public research and educational institutions for agriculture in years ahead is not alone in figuring out how to organize activities for rapid progress in technology. They already know how to do this efficiently. The challenge is in devising research structures which allow digestion of new technology into the economic and social structure to give equitable distribution of gains over the population. Too little concern has been devoted to this problem in the past. Accordingly, some farmers have gained and some have sacrificed from rapid technological gains. Our society expects some penalty to attach to persons who do not take advantage of positive opportunity available to them in growing sectors. Most young people displaced from agriculture choose accordingly and transfer. Others in agriculture step up their operations, to increase output by larger proportion than price decline and thus profit. But there are many people who are not thus situated to adapt and who must bear the brunt of the costs of technological progress which leads to general national gain, sometimes at expense of farm revenue. Certainly the basic problem surrounding agriculture in the 1960's is: How can the rapid supply increase in foods be handled to avert major income burden in agriculture while still allowing the desired rate of progress and in diffusing gains of progress equitably over the population?

BASIS OF PUBLIC SUPPORT

Most less-developed nations do not ask why improved knowledge of agriculture should be promoted. The reason is obvious: to aid in economic development. As mentioned above, organized optimally for this purpose, public investment so allocated needs no other justification. There are, however, miscellaneous and less dirct reasons calling for public subsidization of research and communication of farm technology and organization. One more technical reason for public investment in such a highly competitive industry is: When expenditures have indiscriminate benefit and those who gain cannot be easily identified, public investment is justified. Similarly, where competition is so great that few innovation gains can be retained by those who produce research results, it may be necessary for the community to invest in it.[16] Private firms, of course, conduct research relative to agriculture where they can market a product and gain accordingly. "Early innovators" on farms also benefit from putting research results to use early. However, few firms could conduct research, and retain gain, on improved crop rotations and similar items of technology.

Having looked at some of the broader and more general reasons why publics may wish to conduct agricultural research and development, we now examine some of the more specific and pragmatic reasons. Many land-grant college personnel probably think of their effort as falling in one or more of these.

Alleviate Starvation Potential

This is a sufficient basis for emphasis on improved farm technology in India and similar countries where population presses deeply against current food production possibilities. Looking forward in 1860 and making predictions of the population-food balance over the next century, U.S. society had reason to be concerned about the period ahead. Population was increasing by a quarter to a third in each decade. Agriculture was making parallel strides in output through settlement and development of new farming regions; but the end was apparently in sight as settlement of the more productive soil areas was nearly completed. If future increases in agricultural output were to keep pace with population trends, expansion in the farm plant would have to come largely from a greater output per acre. Two possibilities existed: (1) use more labor and capital per acre (a more intensive agriculture) with techniques known at the time—and a consequent increase in land productivity but a decline in labor and capital productivity or (2) develop innovations which would increase the physical productivity of land, labor and capital alike. Decision was made by U.S. society to emphasize the latter. The decision was wise, and in the last century, population of the United States has increased by 550 percent. Agricultural output has increased similarly, with the major part of the increase in the last half century coming from technological improvement. Starvation has not been a threat, and food demand is not likely to press on food supply in the next half century.

Small Scale of Firm

A further firm basis for public sponsorship of farm technological advances is the small scale of the firm in agriculture. Individual farmers

[16] *Cf.* P. T. Bauer and B. S. Yamey, *Economies of Underdeveloped Countries*, University of Chicago Press, Chicago, 1957, pp. 160–65.

generally do not operate on a sufficiently large scale and do not have sufficient funds for organizing their own research units. In the first two and one-half centuries of United States history, relatively few industrial firms invested in research relating to agriculture. This was true because labor and land inputs dominated agriculture and fewer profit gains were possible from capital inputs developed for agriculture. The investment of industrial firms in technical innovations for agriculture has, of course, increased greatly in recent decades. Development of more and fundamental knowledge in these fields has led to the creation of new chemicals, biological materials and machines which could be produced commercially and marketed in agriculture. Consequently, industrial firms have increased their own investments in uncovering more discoveries. Factor prices and a farm industry resting more on capital inputs have favored this development. However, there are large areas of possible agricultural improvements or scientific relationships which do not result in easily fabricated, packaged and marketed material products or which do not readily lend themselves to patenting and brand promotion. In these areas particularly, farm firms are too small to carry forth their own research. They will continue to require publicly supported research.

Competitive Structure and Small Scale

Another possible basis for public support of farm innovations because of the competitive nature of agriculture is: Society evidently has desired that an important degree of competition be maintained in the American economy. These values are reflected in various types of antitrust legislation. They are related directly to agriculture in historic legislation favoring family farms. An essential characteristic of a family farm is: It is not large enough to exercise monoply power in commodity markets or in the labor or land market. Public sponsorship of agricultural research has likely helped to promote and maintain the competitive nature of agricultural firms. Farming improvements are more equally available to all farmers. This retention of competitive structure has helped maintain family farms, but with the effects of weak market power for agriculture discussed earlier. Farm policies have attempted to give the industry some monopoly power, but retain the competitive nature of the firm. When small-scale firms exist, they are not large enough to conduct research which realizes scale economies possible in this activity. This is itself a reason for group activity in research organization.

Increasing Farm Income

A fourth basis was that of increasing incomes of farmers. Whether or not aggregate farm income is increased or decreased, as a result of technological improvement, depends mainly on two things: (1) the price elasticity of demand for the particular product and (2) whether the technical innovation increases aggregate farm output. Our previous analysis explains the current outcome in respect to this goal.

General Economic Progress

The goal for public investment in agricultural research and education could have been primarily that of economic progress as explained above. This has been its important effect. It is the major basis for justification in the future. In this sense, however, it does need to be emphasized under the appropriate heading and in relation to food and consumer policy. It is possible that this basis for investment may broaden with world economic development and extended political understanding and facilities among nations.

Interregional Competition

Farmers of each region and state can and do look upon investment in research as a method of meeting interregional competition. While it may be known that food demand is inelastic, with decline in total revenue under increased output, a group of farmers forced to hold their output constant while those of other regions increased production, would find themselves to be recipients of a smaller share of a reduced revenue. On a competitive basis, they would be better off, although worse off in both cases, to increase output and have a larger share of the smaller revenue. (See the discussion of equations 5.42 to 5.55 on effects for those who cannot innovate.) In this sense, farmers of each state or region serve in the manner of firms competing with each other and under the necessity of innovation to hold a share of the market. Under the structure of American agriculture, this interregional competition does prevail and causes particular geographic aggregates of farmers to improve technology. Even under a quota system of agriculture, this type of competition would still prevail.

For the Sake of Knowledge

Agricultural research also is conducted for the sake of knowledge in itself. Man has always desired to know more; or parents generally want their children to have an enlarged universe of knowledge open to them. Society obviously is willing to make some investment to this end. As societies become richer, they come more nearly to look upon knowledge as an ultimate or consumption good and invest in it. But to the extent that they do so, emphasis is more likely to be on fundamental research and knowledge. While society may invest some quantity of public funds for this as an end per se, it is apparent that most fundamental research must serve as a means to ends such as those above. It is unlikely that the agricultural colleges will ever be able to justify themselves to farm and consumer publics largely on this basis. In major proportion, investment in improved farm technology needs to be justified where it has greatest contribution: as consumer food policy. It now makes a greater contribution to general economic progress than to farm gain. Relatively, however, its contribution to general progress is less than in earlier times, when farming used a majority of the nation's labor force and resources, and a larger proportionate gain to consumers was possible in the transfer of resources to other industries. As we mentioned earlier, today's farm technological research does not have its greatest promise for today's consumers who are well fed and have calories at low real price. It is for consumers in 1980 and 2000.

EQUITABLE RETENTION OF GAINS

It is in a free market that public investment in farm technological advance is largely an element of food policy. This is true in the context discussed: lower real price of food and reduced farm revenue under inelastic demand. Even when coupled with compensation policy which provides direct payments to farmers or price supports to accomplish the same, it represents food policy for consumer gain. The compensation or transfer payments, either directly or indirectly, simply represent means of redressing the position of those who otherwise bear the cost of this progress. Output is allowed to grow against declining revenue.

There are combinations, however, whereby public action to improve technology could be looked upon as element of farm policy, with focus on increase of farm income rather than on consumer surplus. If, for example, supply of food was restricted to maintain revenue under the inelastic demand that faces agriculture, farmers could innovate to reduce resource inputs and costs of given output. With output and revenue at constant level, technical advance lowering per unit requirements in resources and costs would increase net income of farmers. Any type of innovation which is economic in the sense of marginal cost less than marginal revenue could do so, even if it is a biological development such as new seed variety or fertilization to increase yield per acre. The farmer could simply use fewer acres, lowering costs of attaining output and revenue restraint and thus increasing net income. Hence, within this framework, advancement of technology in agriculture could have the end of farm income improvement and serve as a basis alone as farm policy.

Consuming society could also gain from resource savings allowed to transfer from agriculture to other industries. Still, it also is possible to arrange subsets of policy elements such that they provide even broader gain to consumers, while some gain of progress is retained for farm producers as a broad group. The supply restraint could be gradually loosened so that real price of food is allowed to decline, but not so fast that total revenue to agriculture declines, while farmers are realizing gains through relatively larger decline in per unit resource and cost requirements. (Some of the "saved resources" could also be transferred to other economic sectors as indirect source of consumer gain.) Pareto-optima or Pareto-better conditions thus are attained, with real income gain to consumers in aggregate and money and real income gain to farm producers in aggregate. A wide range of policy mechanisms would allow this, including the regional land reduction alternative or others discussed in Chapter 14.

Another alternative to these more direct supply restraints would be managed rate of technical advance. We illustrated in Chapter 7, equations (7.20) through (7.31) for particular forms of demand and supply functions, maximum rates at which production coefficients might be allowed to change against rates of demand increase, if specified goals in respect to resource use and prices of agriculture were attained. In equation (7.28), for example, technology could increase only at the rate $\Gamma = \lambda^{.2}$, where demand has the price elasticity of only $-.4$ and production elasticity remains at .8 under technical change for the particular algebraic form. (The equations and discussion in Chapter 11 relating to quotas and supply management also illustrate how technology can be furthered with gain to both producers and consumers.) Hence, public-sponsored technological advance at rates managed to attain these goals would be primarily farm policy, with food policy attainment being secondary but with Pareto-better conditions allowed in gains to both consumers and farmers.

Managing the rate of technical change is a more subtle mechanism and would not appear so directly as "market interference," as do quota systems for inputs or outputs, to check supply. Society, of course, does interfere with the market in this respect. It does not allow the market to generate all new technology, but produces it in its own institutions. It has injected technology, helping change the production function at a faster rate than demand has grown. Injecting it at exactly the rate consistent with profit maintenance under demand growth would be no more, and even less than at the present where the public supplies the technology without restraint, a mechanism of market interference. Obviously, however, management of rate of technical change to accomplish this end would be extremely difficult, much more so than other policy alternatives allowing the same attainment. Difficulty arises because the technological potential at a current time is largely a function of research inputs at an earlier period.

Data of previous chapters indicated that existing technical knowledge not yet in full use promises a regime of food supply burdening demand for the next one or two decades. This knowledge has already been partly dispersed and its withdrawal would be impossible. Difficulty also arises because an increasing proportion of research inputs are those financed by private firms. The outturn from these inputs would go on, likely at increased tempo because of profit incentive. Finally suppression of scientific knowledge is not an alternative of general appeal, particularly when it has high returns to general society, and even if guarantee of positive-sum outcome is not apparent over all groups.

Organization of Research for Progress

In some nations, the problem ahead is to organize research for agriculture which has urgency in possible return in national economic progress. This was an important basis for urgency, but unwittingly to those originating it, of research in earlier decades of the U.S. With approach of only 5 percent of labor force in agriculture, urgency for these purposes is now in other areas. But research could be organized readily to meet various sub-goals in general economic progress. Take a nation short on food "necessities" and with a paucity of resources for nonfood development. Developmental goal would be for technical progress and augmented supply function to increase output and lower price of basic food items while freeing resources for other industries. Magnitude of demand elasticity would be a criterion of some relevance for ordering research on farm technology. Research might be devoted especially to commodities with low price elasticity of demand, these being the commodities consumed in broadest expanse by the population and immediately needed to lessen hunger. Also, these would be the commodities engaging the greatest quantity of resources, and presenting greatest potential in resource savings for intersector transfer. This society, not concerned first with farmer income and welfare, would perhaps leave aside those commodities of more exotic nature and with high elasticities of demand in respect to price and income (except for export and exchange for greater quantity of necessities). In any case research promising greatest resources savings would be emphasized.

Now take a contrasting society. It is not concerned with consumer welfare and progress goals. Its only concern is in increase of farm income. Farm technological research in this society would be conducted generally only for commodities with price elasticities of demand greater than unity, plus certain other non-output increasing (to extent that these exist) innovations of an engineering nature.[17]

We can specify other organizations of technological research with criteria in economic growth where supplemental policy is not used to guarantee retention of some progress gains in agriculture. More than otherwise, emphasis in research and education of agricultural colleges over the past decades has been on innovations which increase productivity and output of resources specialized to agriculture. Stress on quantity has been greatest in research which increased yield per acre, output per animal or production per unit of feed. (The traditions and lore of agricultural science evidently have given more recognition to the worker who thus accomplishes, as compared to the one who develops, an improved quality or embodies a new service in a product.) This is the relevant emphasis when either (1) a nation's diet is near subsistence level and (2) the price elasticity of demand for food is greater than one. Neither of these conditions hold true in the United States. Hence, while the paramount emphasis in India is correctly increased yield per acre of staples such as rice, with smallest resource costs per caloric unit, this is not singularly true in the United States.

One set of criteria for ordering biological or physical research and

[17] For some of these classifications, see Earl O. Heady: "Basic Economic and Welfare Aspects of Farm Technological Research," *Jour. Farm Econ.*, Vol. 31; "Adaptation of Education and Auxiliary Aids to Solution of the Basic Farm Problem," *Jour. Farm Econ.*, Vol. 39; and *Economics of Agricultural Production and Resource Use*, Prentice-Hall, Englewood Cliffs, N.J., 1952, Chap. 27.

education in public institutions which are not part of the market in a private enterprise economy, is still reflected through quantities of the market, however. Income elasticities of demand quantities which can be measured and have practical empirical meaning, can serve as criteria. In effect, these quantities indicate that consumers who are well fed and have high incomes (1) take satisfaction of hunger for granted, with worry mainly of obesity, and (2) are more intensely concerned, not with obtaining "commonplace luxuries" such as food, electricity, running water, telephones, radios, cars and a 40-hour week, but with more "exotic necessities" such as hi-fi, automatic transmissions, power boats and automatic washers and dryers. They place no premium on greater physical quantity of food per capita as their income grows.

While the consumer places no premium on the quantity aspects of food, income elasticities show that he does place positive premium on the quality or service aspects which can be incorporated with foods. (See Chapter 6.) Income elasticities of demand, then, could well be used as one basis for ordering biological and physical research on farm products aimed at improving consumer and producer welfare in an economy as wealthy as that of the U.S. Directors of research might lay out before them, for the purposes focal to this section, the complete array of income elasticities for different agricultural products and for different aspects of products such as quality, quantity, service, convenience, etc. Research resources would then be allocated in terms of and relative to magnitudes of income elasticities of demand, weighted by the quantity of resources used for each product. Those products, qualities and services with highest elasticities are those from which consumers will derive greatest satisfaction as their income and total expenditures increase. For this very reason, they are the ones for which consumers will reward farmers most in profit as per capita income continues to grow. Certainly private firms are concentrating research in these very directions (i.e. growth industries) for the reasons mentioned.

Research and education are not purely stochastic phenomena, with chance occurrence relative to their initiation and outcome. They need not serve as exogenous variables, with their direction predetermined by conventions of the past or as by-products of a previous organizational structure. They can be geared to the present and prospective economic or developmental status of a nation. The probability of scientific discovery for a particular product, function or service depends on the size of the sample, the quantity and quality of research resources allocated to it. Quantitative guides, if recognized and used in the administration of research, exist even for gearing physical and biological sciences to the emphases specified by economic growth. An ordering of research in line with these quantities would not nullify the demand for particular specializations in agricultural science, but would only turn the direction of their concentration. For example, plant genetics would be just as important as before, but emphasis would be more on breeding to develop "inward quality and services," rather than quantity. Genes, heterozygote, recessive, dominance, mathematics, chromosome and other scientific concepts and phenomena which serve as traditions of the field would continue so. They would simply be used for more urgent social purposes. The challenge to plant breeding scientists need not be lessened. To the contrary, it could be increased since the quality-service aspects of plants have been less exploited and likely are more complex. The same would be true for the majority of specialized agricultural sciences. We have, then, one approximate basis for estimating the payoff and needed direction of biological research and education under economic growth, starting with a high level of per capita well-being and with further growth on income in sight. Undoubtedly it would call for sizeable increases in physical and biological research relating to food processing and manufacture in stages beyond the farm.

The discussion immediately above has been in terms of public research policy apart from all other policy elements. It is the realm in which directors of research operate, since they cannot individually initiate, legislate and implement other public policy. But where public research policy is linked with public output restraint policy, as discussed previously, any innovation which can reduce input per unit of constant output, revenue remaining constant and costs declining, can serve to increase aggregate farmer welfare. In absence of this linkage, however, elasticities of demand do become relevant criteria of ordering research to guarantee positive-sum certain outcome in attainment of Pareto optima wherein both consumers and producers are better off—producers in increased revenue and consumers in supply and real price of commodities to which they attach greatest marginal utility.

Emphasis on Social Sciences for Developmental Attainment

The criteria above serve as one basis for ordering research in the physical and biological sciences, with focus on innovating services of greatest marginal urgency to high income consumers and, hence, with greatest prospect for monetary reward to farmers. But if appropriate total goals are selected for research in the land-grant universities, growth criteria also relate to the social sciences. Research and education in agriculture have had significant effect not in increasing aggregate farm profits or in creating new and different food utility and service for consumers, but in helping to lessen the amount of the nation's resources required to produce food. Labor and other resources are freed from agriculture so that they can be used to produce schools, hospitals and roads in the public sector, and to produce houses, television, power boats and clothes dryers and the many other goods of "great marginal consumer urgency" in the private sector.

The agricultural colleges and the U.S. Department of Agriculture have been in the vanguard and have been major contributors to this facet of national economic development. They can well pride themselves in it. It has been a major reason for their existence, although it has not always been so recognized. But they should become more cognizant of this contribution and base appeal on it. They will have a broader role and financial support if they do so. They can tie cause and result together, a condition not well attained when justification and financial appeal is based mainly on contribution to farm profits. As indicated above, there is some empirical indication that this appeal and contribution can be recognized by the consuming public, the main sector to gain from the contributions to development by agricultural colleges under conditions of the market. Appropriations for the experiment stations and research services tend to be smallest, relative to value of farm production, the greater is the proportion of state income represented by agriculture. Between 1920 and 1955, agricultural research became concentrated relatively more in the industrial states, high population states or states having products with greater demand elasticities. (Also, states with small initial research investments were able to increase their percentage share of state research appropriations.)

But our main concern in this section is in the ordering of research and education and in gearing it better to national economic progress and guarantee of Pareto-optima or Pareto-better attainment in utility increase over producer and consumer groups. Emphasis on research for technological progress of conventional types (e.g., the quantity facet, as compared to the quality-service facet without regard to magnitude of income elasticities) is justified in the broad economic development framework outlined immediately above. For this purpose, however, it is not sufficient that the resources be freed through biological and physical innovations and then left stranded. Under this condition, they remain in agriculture producing a product. With low demand elasticities the result is surpluses and depressed farm prices, incomes and factor returns. Hence, if the general economic development goal is to be selected as the major justification of biological and physical research of conventional emphasis, it must be accompanied by equally intensive research in the social sciences, if the national development gains made possible by technical research are to be realized rapidly and fully, and if economic misery is not to impinge on those persons caused to become surplus resources as a result of rapid technological progress. Social science becomes an important technical complement with technical science for this goal of agricultural research and education. The former needs to be put on a footing with the latter, a condition which does not hold true in many land-grant universities.

Social science should not be increased at the expense of technical science, but rather increased in magnitude and financial support to the levels which have more often been traditional for the physical sciences. The two go along together for the basic developmental goal. Social science is needed to lessen economic pain for labor and capital resources caused to become surplus by technical progress. The benefits of these resource savings have no basis unless equal activity is devoted to aiding transfer of the "freed" resources to occupational and geographic points where they have premium under economic growth. (Too, there is need for more research and education on social mechanisms which allow this contribution through technical progress, and also allow farm producers to realize reward, rather than only short-run penalty, for contribution made to broad national consumer welfare.)

The investment in social sciences now needs to be large. Magnification of social sciences can actually aid and enhance the physical sciences. Without more intensive social science to help solve the surplus, excess factor and depressed income problems generated by rapid technical progress, technical sciences are much more likely to be restrained by lack of funds. Again, the question is not one of social science at the expense of technical science or vice versa. The problem is to develop total research and educational programs which are systematic in the broad national developmental sense. Here, social and technical sciences go hand in hand and one is needed more because of the other. Without the other, the one is much less meaningful in terms of social gains and justification and is much less likely to have adequate long-run financial support.

Technological research of the type normally conducted, and in a market environment with the traditional distribution of gains and costs, contributes to long-run economic progress by bringing about more output from given resources, or allows the same output from fewer resources or costs in agriculture. Hence, in the long run it allows a growing population or consuming society a greater output and variety of goods from the total available resources. Research of this kind is needed in agriculture in the traditional framework (1) to give farmers of one state equal opportunity with farmers of other regions to realize the potential of technological improvement, (2) to provide a basis for general economic progress and the benefits which generally accrue to consumers, (3) to advance general science and knowledge and (4) to enhance the position of a nation in the competitive world. But in accomplishing these long-run objectives in the normal environment, much of this research gives rise to short-run problems, since the increased output and increased resource productivity are not immediately "digested" into the national economy.

In the short run, increased output gives rise to surpluses which depress prices and incomes or cause some resources such as labor to become excess. With the long-run effects of research of the cost-reducing and output-increasing types desired and necessary for the above reasons, research is needed for: facilitating the "digestion" of potential gains from these other types of research into the general economic or industrial system; lessening short-run problems created by increased output and resource productivity in agriculture; bringing returns to resources in agriculture up to levels in other industries; helping to insure that the gains from technological advance from usual types of research are realized more quickly and fully by consuming sectors, including both farm and city families; establishing means whereby farm people can receive appropriate rewards for their resources under rapid technological progress and an equitable share of gains from progress; aiding in change of social structures appending both directly and indirectly to agriculture and altered by rapid technological advance and population change; bringing about a more efficient allocation or balance of resources within agriculture and between agriculture and other sectors of the economy, considering distribution of gains and costs of advance and "unevenness" in market power; and providing the factual basis for developing positive governmental agricultural policies consistent both with the welfare of farm people and over-all national goals. Generally these needs call for social science inputs on par of importance with physical science inputs.

Systematic Research Programs

It is highly appropriate that land-grant colleges make a systematic analysis of the effects of conventional research and educational programs on income and welfare in both the farm and nonfarm sectors of society; then, after this picture is more precisely established, they should outline the appropriate role and orientation of future research and education in a wealthy and progressing economy. This role is quite different from a century ago and from what many land-grant college staff members still believe it to be. A vigorous and well-supported research and educational program will always be needed, and the returns over the next several decades can be relatively as high as those over the previous century. But the support for this continued investment is most likely to be forthcoming if land-grant college personnel better understand the actual effects of their efforts and develop programs which are more complete and systematic in terms of these effects. Too, they will be better able to appeal for support to those segments of society which actually are the chief beneficiaries of the research, in contrast to the existing situation wherein large benefit accrues to consumers but appeal for financial support is made mainly to farmers.

Another reason also exists, causing this re-examination to be possible and relevant. The private sector of the economy now is extremely important and efficient in development and production of new agricultural technology. Likewise, it is efficient in communicating this knowledge to farmers; appropriately because knowledge serves as resource in the position of a technical complement necessary for productive use of material resources sold by private firms. Investment by private firms in communication, including salesmen, dealers, advertising and public relations likely exceeds that in extension agents and printed materials by the colleges. Too, if measurement extends far enough into fundamental research by private firms, the private sector investment in research for new farm technology probably exceeds the public investment. It is for this reason that underdeveloped countries cannot reproduce the U.S. public facilities for research and education, represented in the agricultural colleges and the U.S. Department of Agriculture, and expect development results comparable to ours over recent decades.

New machinery, ration supplements, fertilizers, improved seeds and even certain aspects of livestock breeding have come to flow largely from the private sector, which has illustrated great ability in applied research, especially in adapting fundamental findings to applicable forms for marketing as capital materials. Because of growing private sector contributions, public institutions for agriculture have an opportunity to evaluate the relative economic urgency of their contributions under economic growth and to divert effort towards those products or services of knowledge (1) apparently still subject to decreasing costs not realized in the private sector, (2) most consistent with the income and growth status of the U.S. economy, (3) not adapted for "package and sale" by private firms but of extreme importance for furthering progress in agriculture and (4) consistent with the actual economic impact of research and education on the various segments of society.

EXTENSION EDUCATION ADAPTATION

Large needs and opportunities also exist in adapting extension education to the economic growth status of agriculture and the nation. Extension is an important tool in helping lift nations of low stages of economic development, and also in helping to guide economic reorganization at high stages of development.[18] (Also see the educational needs discussed in the last section of Chapter 9.)

A basic need, serving as foundation in programming extension education, is for extension services to know that a major effect of their traditional activities has been to replace people from agriculture. As mentioned in earlier chapters, more potent feeds, insect sprays, fertilizers, seeds and other technologies substitute for both land and people in the agricultural production process. The faster these innovations are extended and adopted, the more rapidly are people replaced from agriculture. Then, do the extension services have educational responsibility for these persons displaced by their traditional activities? What goal exists on which this displacement is based? Are the persons displaced any less important than those remaining? Are information and services to ease their transfer not a minimum compensation need? These are questions which not only are appropriate but also can serve in providing direction and broader opportunity for the extension services.

Alternative Views in Purpose

Extension education can view itself largely in the economic and social framework of a century back: when the country was agricultural in the majority and public investment was used largely to increase farmer income. Or, it can view itself in the twentieth century setting, as an arm of general society with its main function to bring about lower real prices of food, to reduce resource requirements and to get these freed resources

[18] Bauer and Yamey (*op. cit.*, p. 217) indicate the need for public service to provide basic knowledge at low levels of development since private sectors often cannot develop and sell applicable innovations at a profit. This statement is even more applicable to problems of change and public choice on policy at high stages of economic development.

transferred to other sectors. It could proceed with the first without concern about positive-sum utility outcomes for all of society. Or, it could proceed with the second in the same vein, with gains from farm technological advance going to consumers, but costs falling on farmers in aggregate as revenue declines under inelastic demand. Let us review possible activities under these alternative "charters."

Several alternative goals could be selected as the focus of educational activities in land-grant colleges. The goal selected largely specifies the means. The means are reflected in the types of information carried to farm people, the types of specialists (animal husbandrymen, agronomists, economists, vocational guidance specialists, etc.) who are employed by the extension service, the relative amount of funds used in low-income counties as compared to high-income counties, the methods employed in contacting people and communicating ideas, etc. Means or educational patterns selected can be either consistent or inconsistent with the end held. Conflicts have existed, and do exist, between (1) major ends or goals which educational administrators use as the allocative focus of their program, (2) the means employed and (3) the actual ends attained.

Perhaps the most widely held goal of extension education has been to increase the aggregate income of farming. If this goal were the only relevant one, the direction of education activity and employment of specialists would be quite clear. Specialists would not be employed and information would not be communicated to increase output where the price elasticity of demand is less than 1.0. Unfortunately, the list of commodities with demand elasticities greater than 1.0 is very small. (See Chapter 6.) Hence, if the goal of extension activities were actually that of increasing farm income, and not necessarily that of maximizing the welfare of farm people, specialists would not be employed and information would not be extended for techniques that increase output of such commodities as wheat, corn, potatoes, hogs, many dairy products, peanuts, cotton, eggs and most other common farm products.

Physical specialists would be those with engineering emphasis, to assist in techniques that lower costs per unit but do not increase output. Biological specialists would not fit into this scheme so well, for although biological techniques lower costs per unit, they also generally increase output. Even an engineering innovation that has first impact in reducing total costs may lower marginal costs to an extent that output finally does increase. The point is that many of the activities traditionally emphasized in education are not consistent with increasing gross revenue of agriculture.[19]

If greater revenue to agriculture were the sole end of extension activities, the means employed are highly inconsistent with the goal. This

[19] Of course it is true that even though demand is inelastic, farmers who first adopt an output-increasing technique, and who do not produce enough to affect market prices, can gain from any type regardless of the demand elasticity. However, the emphasis of this paper is on macro adjustments and mass farmer reaction.

is not to infer the specialists in most types of technological improvement should be dropped from extension programs. As brought out below, this type of activity is consistent with other possible goals of extension activity, if other means are employed with it. However, it is generally inconsistent with the goal of increasing farm income in the free market where demand is inelastic and resources have low mobility. If this were to be the actual goal of extension education, emphasis should be on experts who would help farmers form monopolies and reduce output, at least to the point where price elasticity of demand becomes 1.0.

Maximizing the Welfare of Farm People

Welfare of people in agriculture might be increased generally by any educational activity that extends output where price elasticities are greater than 1.0 or lowers total costs but does not increase output for commodities with inelastic demands. However, welfare also can be increased by extending output for commodities with inelastic demands, as long as the reduced total revenue is redistributed so that the increase in utility to farm families realizing a gain is greater than the reduction to those realizing a loss. Suppose, for example, that output increases by 10 percent from a new technique while price declines by 15 percent. Although total revenue will decline, revenue will increase for farmers whose output increases by 20 percent, but decline for those whose output increases by only 5 percent. Of course, the difficulty of interpersonal utility comparison prevents any easy designation of which group of farm families might gain in utility relative to the loss of others. The activities in extension education do cause redistribution of income and assets. Historically, the effects of education in causing income to be redistributed have been more in the direction of farm families who have the highest income. This tends to be true because these are the operators with the capital for investment and for taking risks in new techniques, and they are easiest to contact.

The goal selected as the relevant framework for extension education not only provides the basis for determining the allocation of educational resources among (1) fields of subject matter specialization and (2) geographic and income strata of farmers, but also in specifying the communication methods employed. If the goal were mainly one of "providing educational services to those best equipped to acquire them" (usually farmers with ample capital and education), then communication methods could include only meetings at state universities and colleges, television programs and technical bulletins. The intended consumers would have time, foresight and funds for coming after the information. However, if the goal is one of maximizing welfare of farmers, with emphasis on increasing utility of farm families who have low income, the communication system needs to be quite different. It cannot be in terms of mass media. The low-income farmer may not have the funds for a television set or a trip to the state college meeting; he may not be able to understand a highly technical bulletin. The communication method more nearly needs to be one of "taking the educational input to the farm."

If general economic growth were selected as the central end or goal of extension education, the means for accomplishment might be various. Investment can be made in specialists to promote techniques for products with inelastic demands. With minimization of resource inputs for subsistence goods being a subgoal, the "lowness" of the price elasticity might be one relevant goal for allocation of resources to products and extension specialists. Educational resources then need not be allocated to conform with any income distribution pattern or framework of communication media, but should be used where their marginal productivity is greatest in increasing the output per unit of those resources that are mobile and can be used elsewhere in the economy. However, an important means, complementary with those means directed towards minimizing the amount of labor used in producing subsistence food products, is that of facilitating the movement of labor from agriculture, once it has been "freed." To free labor from agriculture and then leave it stranded is as inconsistent with economic growth as in not having freed it in the first place.

Selecting individual goals, such as those discussed above, allows selection of particular methods. They can be pursued with vigor when inconsistency between goal and outcome of means is not brought to question. The same is true where we attain one end with means efficient to it without concern of distribution of costs and benefits resulting from the progress or reorganization so fetched. But on the other hand, we can concern ourselves with the distribution of these gains and costs, and with possibilities of negative-sum outcomes when sacrifice to some groups may be larger than reward to others. When we become so concerned, then ordering of educational program in the vein outlined above for research programs becomes appropriate. Without policy linkage, we must look for educational activities which promise to increase farm income as well as consumer surplus, if our effort is based on farm policy and positive-sum utility outcome is to be guaranteed. If gain is certain only for consumers in lowered supply price of food, and loss to producers is certain through greater output and smaller aggregate revenue, the educational activities best serve as consumer policy. But with policy linkage as mentioned in a previous section, gains to both consumers and farm producers can be guaranteed and agricultural education again becomes an element of farm policy and general economic growth guaranteeing positive-sum utility gains.

Broad Needs in Education

Education is near the human resource and it needs to be handled accordingly, as emphasized in relation to phenomena of Chapters 12 and 13. Faced with further economic growth, extension services will need to concern themselves much more with people, and in aiding them to make both private and public decisions.[20] They need to lead the way in helping farm persons understand their individual capacities and means for most opportunity expression and gain from their particular abilities. As outlined in Chapter 12, much of this need is in direction of guidance, counseling and job information. Extension services have done well in providing hogs with market outlook. They need to do as well with people. The important educational need, as part of the extension service's challenge in and contribution to economic growth, is in providing knowledge that guides farm people to their most promising alternative in life. This activity has been submerged by the flow of technical information. It needs to be made a main focus of educational activities and can become the foundation stone of agricultural policy designed to solve income problems stemming (1) from both economic growth and a relative depression of farm prices and (2) from paucity of resources and true poverty of farm families.

The needs and opportunities in extension education were never as broad as at the present time. The extension service represents an educational mechanism of great value to society in its decision-making processes relative to changing structure and national needs under economic growth, for either group or individual choices. Whereas its traditions were established in gauging the possibilities for plants and animals, it can now do so for people. To be certain, it can and should retain activities which focus on technological improvements, since these have been part of the public investment returning the large progress payoffs mentioned earlier. But it can go much further. First, it needs to extend its services surrounding the individual much as it surrounded plants and animals in the past. This is part of guidance and counseling efforts already mentioned. Then, it needs to extend further to communities with these same processes, helping them to assess their production possibilities, in deciding to invest in local industrialization or to help surplus labor migrate. It needs to help individuals and communities see their interdependence and interrelationships with the national economy, with choices made accordingly in geographic, occupational and social commitment of resources. Finally, it needs to teach basic or general economic principles to people so that they will have tools for making evaluations and choices consistent with individual preferences and group goals.

In this latter respect, we re-emphasize the points made in Chapter 9:

[20] Grant McConnell reports that the land-grant colleges devoted little attention to people until the 1944 Land Grant Policy Statement. Since that time, of course, farm and home planning and rural or area development programs have taken effort more in this direction, as have orientations around the "scope report" and similar statements of philosophy. Political struggle revolving around possibilities of educational aid to the lower-income strata of agriculture also is discussed by McConnell (*Decline in Agrarian Democracy*, University of California Press, Berkeley, 1957, Chaps. 8–11). Soth (*Farm Trouble*, Princeton University Press, Princeton, N.J., 1957, pp. 88–94) suggests need for transfer of emphasis from the technical service activities for higher income farmers little interested in fundamental education to the more fundamental needs of distressed persons. He indicates that the technical services can be handled quite appropriately with mass media or as a marketable service.

People make choices through the pricing and voting mechanisms. Through the second mechanisms, they specify their selection of public policy. But often they operate in a knowledge vacuum, not knowing which ends are complementary or competitive, the predicted outcome of various means, the interrelationship between ends and means and other interrelationships within this general complex. So short is knowledge, that a policy choice often serves as a pure experiment: to try it out and see how it works. The decision-making process can be made more efficient where voters possess greater information. The extension services can provide more productive services for public choices, just as they have done for private choices. They can be objective in this process and thus gain wider public recognition and demand for their services. Given effort in this direction, they should have little concern with having to "burn the books" as result of the pressure and group antagonism mentioned earlier.[21]

Stage of economic growth gives rise both to need for these broader activities and to opportunity to engage in them. It is nearly a "natural law of economic growth" that increasingly, with passage of time, details of farm technology will be furnished by private firms. In early stages of growth and factor prices, agriculture rests mainly on labor—a commodity which private firms cannot process and retail. But with growth and change in factor prices, the transformation of agriculture calls for more of technology to be in the form of capital inputs which can be produced and retailed by private firms. They can and do invest heavily in retailing this practical knowledge to farmers. Extension services thus can be relieved of much of the detail of technical services and can devote an increasing proportion of efforts to (1) the more fundamental principles and knowledge in the physical, biological and social sciences and (2) the more urgent social decision and adjustment problems. A relatively higher public investment also is required to take a given amount of fundamental principle in biological and physical science, and general knowledge of social science facts and understanding, to people. This is true because the facts and principles so represented are not "packageable commodities," as in the practical findings of physical fields.

In accepting the broader and more fundamental educational challenge, extension services even can lead in the transformation of rural communities. As mentioned in Chapter 10, precedent can be set for communities by regional extension offices which provide activities broad enough for employment of more specialists. These specialists are needed in the extension of fundamental principles of biological and physical sciences. They are needed equally in the fields of social sciences: to provide guidance and to help families and communities to inventory their resources and possibilities, and to make decisions which are commensurate with their opportunities and capacities.

---

[21] For the problems, forces and methods encountered in handling "book burning pressures," see C. M. Hardin, *Freedom in Agricultural Education*, University of Chicago Press, Chicago, 1955.

THE BROAD ROLE AND APPEAL

The time has come, in fact, when the agricultural universities and colleges should see themselves in the broad framework of contemporary U.S. society and its problems. There is need and opportunity for greater role and support than at any time in previous history. The agricultural colleges represent resources not only for promoting domestic economic growth, but also for helping to attain the international goals and responsibilities of the nation. A responsibility necessary and assumed by the nation is promotion of economic development in countries of less progress. This responsibility and intermediate goal will grow in emphasis because of (1) growing world public opinion favoring freedom from hunger and self expression by all peoples and (2) interrelated world political and economic competition. In furthering these long-run goals, and if the broad public role should be taken seriously in agricultural colleges, personnel in both the technical and social sciences should be allocated much more to international problems. What is needed is not so much the "remote" inter-university relationship between U.S. and foreign universities, seldom considered to be an on-campus activity of most institutions, but rather an activity which is an integral part of on-campus efforts. Under more "direct" engagement, a research worker at one college would be assigned as directly to development improvements for a foreign location as is his colleague in developing an improvement for a particular county in the state. But this is a development, however important, which currently lies outside the financial and jurisdictional opportunities of states, either singularly or collectively. It must await intensification and clarification of national purposes and emphasis.

Somewhat strangely, many agricultural colleges have viewed research in foreign economies and development to be out of their realm. Such projects are completely subordinated to small local projects and are not supported at all in most states. This is true even though (1) most agricultural colleges consider themselves to be working in behalf of farmers and (2) the single major opportunity for increasing income magnitude (and justifying increased agricultural productivity) is in developing international markets and institutions to allow the hunger and population problems of other countries to be solved from the U.S. supply of food. If the sole goal of agricultural research and education were farmer income, it might be best attained by shifting a large proportion of personnel and financial resources over to this investigational area and in developing a breakthrough in large foreign market outlet for U.S. foodstuffs. In balance with other goals and among the relevant sciences, this extent is not needed or desired. But certainly more emphasis and work in this direction is needed.

APPEAL TO CONSUMERS AND PATTERN OF FINANCE

In a similar but less worldly vein, the agricultural colleges need to tackle the problem of broad national recognition, justification and support of the system, even to the extent of adding "food" to their title. This is a task which is not best accomplished by individual states, but by a comprehensive approach of the land-grant college system. It was less, or was not, necessary with initiation of the agricultural colleges when most of the population was farm. In another 25 years, the farm labor force will be less than 5 percent of the national labor force and net farm income may be only 2 percent of disposable personal income. The numerically great and economically significant sector of society benefiting from conventional agricultural research and education on technology will be the consumer, as it now is. One hundred percent of the population will have contact with the public institutions as food *consumers and households*, but a small and declining fraction of the nation's *resources and producers* will have any tie to the efforts of the agricultural colleges. Without wider recognition of this fact, and of the true role of the agricultural colleges, and without financial appeal and programs bent more in this direction, the institutions stand to face an increasingly difficult "uphill climb" in competition for public funds for these purposes.

Financing Gain From Technical Advance

Change is suggested not only in the over-all structure of technical programs for economic progress and consumer benefit in real food prices, but also is desirable in the regional pattern of specialization and financing of research and education. To the extent that demand elasticities were high enough to cause farmers in aggregate to benefit directly from technical advance and greater output a century back, it was highly consistent that farmers and citizens of farming states be asked to provide the main funds to support the corresponding research. They bore the costs and realized the gains, the latter in general exceeding the former. With a different status of national economic development and demand elasticities, and with the major beneficiary of greater output being the consumer, it is now less appropriate that farmers and citizens of the agricultural states be asked to finance research and education to benefit consumers in other states. This is, however, partly the pattern which exists for state funds used in research and education, the majority of funds going into technical improvement.

Should not a much greater proportion of funds aimed at technical improvement be obtained on a national basis, with the pattern corresponding more consistently to consumer concentration, then be allocated back to states on the basis of concentration in agricultural production, with research conducted accordingly? Or more specifically, should Kansas wheat farmers be asked to pay for technical research which benefits Bronx consumers and, through greater output, reduces revenue from wheat? Given the current day distribution of benefits from improved agricultural technology, an affirmative answer to the latter question would not seem appropriate. The preferred source and allocation of financing would (1) allow research and education to be emphasized and conducted more in line with the regional concentration of agricultural production over the nation but (2) allocate costs more consistently with the pattern of gain to consumers over the nation. In contrast to the "rough" trend of 1920–60, a relative shift in magnitude of agricultural research funds for agricultural states as compared to some industrial states or others of smaller proportion in farm/nonfarm mix in output, this pattern would result in a more productive application of the total national research investment. We are talking here, of course, about technical research in the conventional manner where there is not certainty of positive-sum outcomes, because gains of progress are distributed to some and losses fall on others. Under policy which guarantees mutual and simultaneous gains to consumers and producers (see discussion of earlier sections), the need is different. Some commodities and services have high demand elasticities and are not tied to state locations. This "farm" research can be conducted as readily in industrial states as in agricultural states.

American society has partly recognized this problem by appropriating funds at the federal level which are then allocated to states for research and education on commodities with inelastic demands, as well as for other products and services. These funds are collected somewhat in proportion to gain, through income and other federal taxes, and allocated back to states largely on a farm population basis. Yet major resources for research on these products come from states where they are produced, and not from states of consumers of the same products. Appropriations for research relative to the value of farm production tends to be highest in states with large consumer populations or large industrial output relative to farm output perhaps partly as a further realization of this gain, as well as for youth, family and gains from services and commodities with more elastic demands.