7

Structure of Agriculture

DATA OF CHAPTERS 4, 5 and 6 lead us to the proposition that major imbalance of agriculture can be lessened but little from the direction of domestic demand, by, increasing consumption sufficiently that excess resources do not exist and returns to factors are comparable with those in other economic sectors. Hence, major adjustment apparently must come from the direction of supply and quantity of inputs committed to particular commodities, lessening of inputs and outputs so that returns are increased. The latter can be accomplished through the market, or through policies which restrict inputs and outputs. Farm groups would harmonize if demand could be increased to erase the problem of low incomes and resource returns. But when balance must be restored through the side of supply, agreement on method is not so universal. To understand what is implied in structure of agriculture under economic growth, if major structural variables are to be changed, we need to review prospective directions of agriculture under further national development.

PRESSURE OF DEVELOPMENT ON STRUCTURE

The employment of resources and the mix of products of an economic system change under development in the manner outlined in previous chapters. The changes in structure of agriculture partly reflect those of the national economy, but more so on the side of resource mix than in product mix. This is true since the same developments in factor markets and prices which cause nonfarm sectors to employ a richer mix of capital relative to labor function similarly for agriculture. On the side of product mix, however, the relative shift under rapid or continuous development is much more away from food products and other biological necessities to commodities and services which have greater appeal and marginal utility in convenience and psychological orientation. Of course, the structure of agriculture is caught up somewhat in the same shift in consumption as consumers grow wealthier. As the income elasticities of Chapter 6 illustrate, the makeup of the food product mix, even aside from incorporated processing and marketing services, shifts from inferior goods with income elasticities smaller than zero but representing low cost in calories and appeasement of hunger, to foods of higher per unit cost but containing greater proportion of protein, calcium and other nutritional components. But, because of biological restraints, satiation per capita in food is approached and the over-all mix cannot change continuously over time to the extent of the national product.

There is a fundamental requirement in farm and food policy, if it is to provide a reasonable or workable combination of income stability, compensation for progress sacrifices, opportunity in growth, market power and other goals desired or attained by major social groups. This requirement is that the basic trend in resource allocation and product mix, which stems from economic development, must be recognized. Unless it is, mammoth surpluses and large public costs in storing them arise, as has been the case since 1930, and void exists in opportunity or facilities to provide it for youth and other persons who have greater opportunity in real income and self-expression in growing nonfarm sectors.

Self-administered and legislated powers in other groups may have provided greater market power and income stability than in agriculture generally. However, even with these opportunities and mechanisms, nonfarm sectors have not caused or have been unable to cause the historic mix of products to be so tightly maintained over time as held true in agriculture during the 1950's and early 1960's. Perhaps this difference has grown partly out of ability of particular sectors to manage supply and schedule prices according to marginal urgency of consumer preferences. But more than that, it has been the change in pattern of consumer preferences, the slope of the indifference map, as per capita income has increased, and the broad pull of competition over firms and sectors in a large and complex economy which have caused nonfarm resources to change in pattern of allocation under economic growth. As we have mentioned in previous chapters, nonprice competition and short-run stability have not obviated long-run competition on a nonprice basis—including creation of new products. Ability of oligopolistic industries to administer production and price policy in buggies, kerosene lanterns and wooden matches could not have caused their supply to be maintained and consumers to use historic quantities of them, even at some modest subsidy.

We need, then, to examine the structure of agriculture as it might develop further under the pull of economic change and inter-industry competition for resources. It is not necessary, in terms of portion of nation's resources represented by agriculture and over-all public purposes, that this structure be attained immediately. It could be attained in a relatively short-time span by simple public policy, namely, that of completely free markets and prices. The need or ability of agriculture and national economy to absorb change of this rate and abruptness, as reflected in policy, has been questioned by American society. The questioning undoubtedly rests on the concepts of equity in distribution of gains and costs of progress outlined in following chapters.

This is not to say that farm policy has completely blocked change in agricultural structure. It has not. It has only slowed down the rate of change in technology and resource structure, perhaps only modestly relative to that which would have occurred in the absence of price policy and public compensation. Still, the structural possibility of the agricultural sector under continued economic growth needs to remain in sight of policy formulation. There are several reasons for this. One in conventional economic logic is, of course, that given the technology and consumer preferences of the time, some best or optimum allocation of resources will prevail for the particular economic regime. Increasingly with time, this argument has less significance, although no less logically than for other sectors, as agriculture declines to a minor portion of the economy in terms of portion of resources used and national income generated. But just as it falls to minority magnitudes in this sense, agriculture also becomes too small to ward off the complete pressures of the market under economic change.

To take U.S. agriculture in one direction in 1800 was almost to take the national economy with it. But to take agriculture in a direction differing from the national economy today is quite a different thing. Only discrete legislation prescribing exactly the size and resource makeup of farms could pretend to do so; and even then it would have difficulty as labor responded to off-farm employment and price opportunity, or as capital is substituted for labor in response to relative prices favoring this shift. Simple policy measures, as lower prices for resources such as credit and knowledge, cannot check the stronger pulls of the market in a dominant nonfarm economy.

Finally, there is no evidence that values of society, and those of farm people in particular, prefer perpetuation of an historic agricultural structure, to a point several decades into the future. There is not evidence to indicate that child-bearing farm families wish to have opportunities for their off-spring restricted to agriculture, or to have a structure of agriculture maintained to fit their grandchildren as it fitted themselves or their ancestors. There is empirical evidence that farm persons generally have desired better opportunities for their children than was their own lot. They have not preferred this necessarily to be in agriculture. The empirical evidence is given in the high value and priority given to education and training by each new wave of pioneers which moved westward.[1] Whether

[1] Cf. Douglas C. North, *The Economic Growth of the United States, 1790–1860*, Prentice-Hall, New York, 1960, p. 155.

the resources were logs or sod, schoolhouses arose about as rapidly as farm domiciles. But even more now than previously, young farm couples predominantly wish for education and training which prepare their sons to be engineers, doctors and business executives. While it is common to find hopes that one child may take over farm operations, if they grow successfully, this is not the dominant wish forced on farm children. It never has been, as migration figures and early investment in education illustrate. It is misleading for economists and farm leaders to expound this wish as that of agriculture. Delve into it deeply and one finds it to be not so, this supposition that the farm population wishes an "Indian reservation policy"—one which would maintain the structure, culture and philosophical role in society only as it has been in the past. Farm people of this generation do want policy which gives them promising economic opportunity, and which puts them on equal footing with other industries in respect to market power, income stability and preservation of equity. But they do not look to a cluster of policies which holds agriculture to resource and price structure of the past and present as a foundation of life and living for their young children or grandchildren.

Distinction needs to be made between values of society and farm people for policy of the present generation, over-lapping as it does with the next, and that for future generations. They generally point to two different poles.

Prices, Knowledge and Powers of Markets

Hence, given the pressures of the factor markets and development of technology favoring change in structure, it is useful that image of future industry and firm mold of agriculture be viewed. Projections of its structure can aid in education and action programs in the sense of providing an intellectual environment for decision of individuals, in respect to commitment of their own resources or as voters making choices regarding public policy. It provides a basis also for decision concerning whether a particular trend direction should be diverted or slowed down. But, largely, projection of future potential in agricultural structure serves best to indicate policy consistent with current goals but allowing progress towards longer-run national goals and economic development possibilities. This is not to say that structure as it develops more or less automatically under economic growth is God-given and transcendental, or that it should be man's master rather than his slave. Public policy is needed mainly because of growth and change, and to guarantee positive-sum utility gains from progress, in aggregation of welfare over all major strata of society.

It is the function of policy to assess the impact of this change, modifying the effects where community welfare promises to be lessened materially through sacrifice of particular groups, or speeding it up where it gives rise to potential welfare increase to aggregate society. The structure implied under true economic growth, in contrast to social change where population grows against supplies of capital and commodities, provides basis for increase along the social welfare function. The day is still so far away when the marginal utility of all goods and services for all members of the U.S. population approaches limit zero that further economic progress can be abandoned. As long as this is true and as long as change in structure of agriculture can add to social welfare, anthropological retrogression to primitive or animal cultures aside, markets in the private sector and policy in the public sector will compose a matrix with elements encouraging change.

Given the degree of "under-development" in even the most developed nations of the world, the crucial policy question is not one of how change in agricultural structure can be brought to a dead stop. Instead, it is one of how policy can adapt rate of change to that which is consistent with values of this generation of farm people and society, or to that which is consistent with ability of the remainder of the economy to absorb. Further, it is one of encouraging change but guaranteeing equity in income distribution and in the distribution of the fruits of progress among various strata of society. Policy which tempers progress to conform with these two conditions will have general public basis or acceptance, although not necessarily approval by groups who would benefit more at the expense of others under more revolutionary change.

American farm policy since 1930 has not "zeroed" structural change or technical progress of agriculture. Alone, it has had insignificant effect. We can even hypothesize that the greater certainty it has provided in price and income has effectively speeded the rate of technical change, both in causing farmers to make resource substitutions otherwise consistent with extended planning horizons and in reducing the discounts and restraints of uncertainty. At most, compensation policy has been a method of "buying time" and checking slightly or somewhat the rate at which certain changes in structure have taken place. Quantities cited earlier, on rate of migration, increase in farm size, capital investment, labor productivity and other items of change, indicate clearly that even the retarding elements are difficult to isolate. It has not been an absolute and outright limit to change. Neither will future farm policy be so, as it takes place in a market of national economy so large relative to agriculture that it completely over-rides this sector.

In the sense of buying time, the positive and beneficial aspects of previous policy have probably been in giving farm people added time to gain in knowledge and understanding of the national economy, economic development and the relation of agriculture to both. Regardless of the fact that the farm sector has been blessed with public machinery for adult education not provided other strata of society, this mechanism was used hardly at all in early or previous decades to inform farm people of the phenomena most basic to their economic welfare and decisions, namely, the interrelationships of agriculture and the national economy under economic growth.

Only a minority of farmers had rough knowledge of the nature of demand elasticities. Accordingly, they hoped for the impossible, such as relieving farm income depression through greater output and efficiency improvements in the marketing system. Subsidies and price supports made it possible for some farmers to maintain a living level which kept them in agriculture, particularly older persons without income and progress aspirations drawing them to other industries. For many, it gave time for learning more clearly of the role and prospects of agriculture under economic growth. Farmers beyond middle age at 1950 associated, from their experience in two inflations and depressions, agricultural prosperity with general prosperity in the economy. Farmers beyond middle age at 1960 no longer made this direct association and many even knew, some with the help of their state extension services, the general magnitude of demand elasticities, the prospects in capital and managerial requirements for the developing agriculture and even the relative prospects for growth-oriented employment for their sons and daughters in nonfarm industries.

Policies of the 1950's purchased time in the sense that they provided income supplements so that more farm families had time to learn these things without driving themselves and their children into blind allies; in allowing debate and consolidation of beliefs in respect to value orientations for policy; perhaps in providing surpluses of such magnitude that pressures led to their use in international humanitarianism, when the opportunity likely would otherwise have been absent; and so that an excess of labor was not driven into labor ranks in brief periods of unemployment. Aside from these positive elements, policy of the decade did little to correct the structural imbalances of agriculture, and accomplished certain of the above at public costs higher than necessary for the same level of accomplishment.

At this point in time it cannot yet be proven that certain developments in the knowledge of nature of science have made a positive contribution to man. Atomic fission falls in this category to date. Although its promise of benefit is great and some small peaceful contributions have been realized from it, man is largely its slave. Contemporary societies divert large sums from consumption and human betterment because of it, and cower in fear because of possible consequences of its use. Farm technology is not so awesome, and its potential and very real contribution to human welfare is closer at hand and is not a weapon for mutual extermination by competing nations. But U.S. society cannot yet prove that net benefit, in the sense of gain and loss distributions which guarantee positive-sum utility outcome, has resulted entirely from the rapid output progress of the years 1950–60. It has given rise to frustration within agriculture and by the general public in trying to assess its results and the relative merits of the alternative structure to which it might draw agriculture. It has, on the one hand, caused depressed farm income because of the rate at which it has, along with compensation policies, shifted the commodity supply function against factor supplies and commodity demand of relatively low elasticities. Society, in general, has had to provide large sums and, through taxation, has had to divert expenditures from alternative lines of consumption because of its income-depressing effects.

Because of the rapid entry of farm technology, and inability of farm groups to agree more nearly on policy means and objective, large investments have had to be made in storage facilities for large surplus stocks which accumulated and added nothing to net social welfare. Man was somewhat the slave of technical advance and some of his own farm policy configurations during the 1950's, not only in the sense outlined above, but also in the manner of the competitive model outlined earlier.

Ideally, man would be the master of technology, as well as of the market, adapting its rate and uses to his own benefit. Largely this has been true, but not necessarily for the phases of technology and the time period mentioned. Man can be the master of technology, but he must incorporate it into appropriate policy and economic and social bounds and institutions. It is not God-given that man must adjust himself to rates of technological change and their impacts which are brought about by the undirected play of markets—in India where the market regime may cause the rate to be too slow, or in the United States where it may cause the rate to be too fast. American society did not, in fact, accept the rate of the market, but assumed the function of research in, and communication of, technical knowledge for agriculture. It is not an inalienable law of nature, over which man does not or should not have control, that technology developed must be allowed unchecked momentum in reducing the number of farms by 90 percent in Iowa or Kansas, and the particular distribution of gains and social costs of this transformation.

Variables in Structure

Technical advance, cultural change, economic organization and political mechanism have together promoted economic development and have even lifted man from the status of primate. Technical advance has been the necessary condition, the social structure, the sufficient condition. Man's innate ability to organize would have been for naught without mastery of nature and technological advance. But technical advance in the absence of organization would not even have carried man to the economic status of the Middle Ages. This emphasis is made to indicate that we do not believe economic structure which evolves in various stages of economic growth must be taken as given, without ability to adapt it or turn it in preferred directions. We do, however, believe that a systematic set of variables, with ordered coefficients attached to them, evolve under economic development, whether the social system is one of a completely managed economy or its opposite, a pure market economy. The environment lending force or magnitude to these variables and their parameters will persist as long as development takes place in the sense of increase of ends relative to means; as long as technology and capital accumulation leads to prices of these resources which are low relative to labor; and as long as all possible preferences of consumers are not satiated and differential ability in biological and psychological absorption of commodities and services prevails.

Economic growth is a systematic process in the sense that its different stages and phases in the continuum encourages, through relative differences in factor supplies or scarcities and in factor prices, different technology and resource structure to prevail where alternative technologies are known, or causes premium to attach to uncovering of particular technologies where they are unknown. As development progresses and capital becomes more abundant relative to labor, technologies which encompass greater scale economies to capital and cause higher marginal rates of substitution of capital for labor are encouraged, just as is research to discover and develop them.

We discussed this "natural order" in Chapter 3, illustrating how, at low stages of development with largeness of labor supply relative to capital and smallness of labor price relative to capital, labor technologies with limited scale economies tend to be optimum; but with high rate of economic development and the opposite of factor supply and pricing, technology emphasizing capital and extended scale economies becomes more consistent with economic structure. (See discussion of Figure 3.1 and Chapter 15). Within the continuum of economic development, the direction of American agriculture still is towards the latter pole. If all technology had been known at the outset but capital and labor supplies existed as they did two centuries back, the trend in structure of American agriculture would still have been highly similar to its past. In early decades, with elastic supply and small price of labor relative to capital, technique of production would have favored a large proportion of labor in total inputs. Under labor technology, or technologies using a large proportion of labor, scale economies or cost advantage for large units is not great. Hence, a larger number of small farms exist, with a greater proportion of the inputs furnished directly by the households in agriculture. But with economic growth and shift in price relative between capital and labor, substitution of the former for the latter is encouraged and technologies which increase the substitution rate are especially of mechanical nature, wherein cost advantages more clearly lead to large output per firm.

With greater capital per worker, output per worker is greater, requiring a smaller labor force and farm population with larger and fewer farms. While not quite so restrained, the trend in farm technology would still have been largely over man and hoe, man and animal, man and small power unit and man and larger power unit, had all technology been known over the centuries but with capital supply increasing and its price decreasing relative to labor with economic growth and time. Roughly, the pattern of technology outlined above extends over national boundaries of today's world.

Labor technology and small units exist in less developed nations, not necessarily because of "backwardness" and complete lack of technical knowledge, but because of abundance of labor relative to capital and stage of economic development providing less industrial opportunity for drawing labor from farms. It is not purely a mark of differential efficiency that 75 percent of national labor force is employed in agriculture in India, or that 40 percent is required in Russia and less than 10 percent in the United States. Mixes in these directions are, or have been, consistent with the level of economic development and the relative supplies and prices of capital and labor in all three countries.

Long-run trends in relative prices of labor and capital items used by U.S. agriculture are summarized in Table 7.1. The effect of the growing cost of labor relative to capital, or a declining real cost of capital relative to labor, is that expected under economic growth wherein capital supply becomes large and labor becomes relatively more scarce and expensive to the total economy. Agriculture has changed its structure against these shifts in relative factor prices about as theory would lead us to propose, namely, capital has been substituted for labor with each man who reremains handling a greater aggregate of nonhuman resources. The process will continue, not only because of the direct substitution of capital for labor, but indirectly as nonfarm wage rates act as a magnet drawing labor from agriculture. Farm policies of recent structure can do, or have done, little to retard the latter. Even the cost of transportation and communication has declined relatively to labor price, requiring farm people less real investment in obtaining knowledge about nonfarm employment opportunity or about the technology of capital/labor substitution.

These forces will continue to pull American agriculture in the direction of larger and more specialized farms, resting more on machine capital and less on labor, and more on biological capital and less on land. Change will not be discrete and revolutionary, but gradual and continuous as it has been in recent decades. Whether this trend over the longer run is considered "good" or "bad" depends on the values of the individual, or the goals and values of the nation. Reduction of commercial farms to a million or of total farms by 60 percent, a physical opportunity which already exists when it is noted that 39 percent of farms produced 87 percent of output in 1959, would indeed diminish the effect and power of agricul-

TABLE 7.1

INDICES OF PRICES FOR CAPITAL ITEMS FOR U.S. AGRICULTURE, 1910–59
(1910–14 = 100)

Resource	1910–19	1920–29	1930–39	1940–49	1950–59
Short-term interest rate	95.4	94.0	88.0	78.3	77.1
Farm wage rates	123.7	182.8	121.4	309.4	521.7
Farm machinery	114.9	154.2	149.0	189.0	321.2
Fertilizer	122.1	137.8	104.6	121.0	153.2
Seed	125.2	145.3	106.9	179.5	259.2
All capital items	118.4	119.5	117.9	183.7	259.2

Source: *Economic Report of the President*, 1960 and USDA.

ture in national culture and politics. But whether farm population constitutes 5 or 8 percent of total in 1980 is not highly significant—either magnitude being too small for dominance of the industry over the affairs of the nation. The shape of economic development has already largely accomplished this diminution for the industry as a whole, given wide variance in interests of commodity, regional and income groups of agriculture (although dominance by agriculture still prevails in selected state economies and legislatures). To the contrary, national society has had sympathy with agriculture and has extended policies to it in compensation for sacrifices growing out of progress and to provide it with income security and market power paralleling that possessed by other sectors in the national economy.

GROWING INTERDEPENDENCE WITH NATIONAL ECONOMY

Growing interdependence of agriculture with the national economy is itself a function of economic development. This fact and the relationships expressing it could be measured in time-series sense over the history of the United States, or in cross-sectional manner over the boundaries of nations at varying levels of economic development. Subsistence agriculture and dominance of inputs supplied by farm households characterizes the industry at low stages of development. Labor is the major resource, with land being important to capital generated either within or outside the industry.

Consumption of farm households similarly rests on physical product of the industry and few of the services incorporated with the food flow from outside industry. But with economic progress and relative increase of labor price relative to capital, technology favoring supply of capital from outside develops or is encouraged, giving rise to an agricultural product composed less of labor and land furnished from within the industry and more on capital furnished from outside the sector.

Too, as income increases, the preferences of farm consumers develop not unlike those of nonfarm consumers with rising incomes. Communication in developed societies is too great to allow long-term dispersion in values between farm and nonfarm persons. With media such as television, radio, newspapers and magazines, automobiles and expansion of scale economies to the re-districting of schools, the trend will continue. Hence, development of the national economy impinges on agriculture from the side of production with a growing proportion of nonfarm inputs. It finds agriculture leashed more tightly to factor prices and technology of national markets, with income increase or decline more directly related to the allocation of resources in line with preferences of consumers, and from the side of consumption with families depending less on farm produced foods, using more of the nonfarm services mixed with foods and preferring an "affluence mix" of commodities not unlike middle income groups of other sectors.

Figure 7.1 illustrates the increase in proportion of inputs purchased by agriculture and the decline in inputs supplied directly from farm

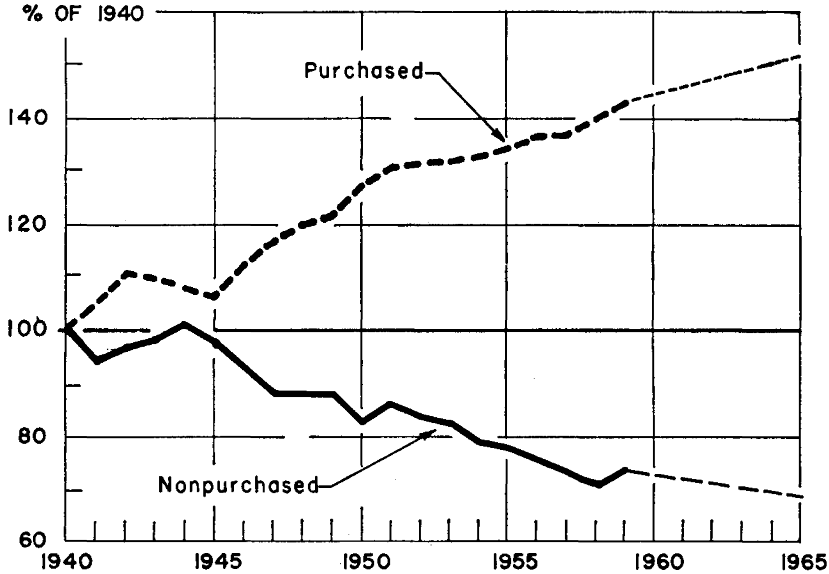

Fig. 7.1. Trends in Purchased and Nonpurchased Inputs of U.S. Farms. (Source: USDA Neg. 60 (10)—9020.)

households. This trend can only continue because of the limited area of land, and because of further substitution of capital in new technology for land, and because of capital and labor prices which extend the degree of mechanization. This increase in proportion of "outside" inputs causes income and structure of agriculture to become increasingly sensitive to prices of the nonfarm economy. It places greater pressure on agriculture to adjust resource structure and output with consumer preferences as expressed in commodity and factor markets.

Regional and Commodity Interdependence

Interdependence of agriculture with the nonfarm economy varies among regions and commodities, depending on the products of advantage and the general nature of the production function. This degree and variation in interdependence can be illustrated partially, and imperfectly, by review of coefficients derived in input-output models emphasizing agriculture. The models presented have the implications and limitations outlined in the following summary of the models. Open models of the economy were used. The basis or descriptive phase of the models can be written in the notation of (7.1).

$$
\begin{aligned}
X_1 - x_{11} - x_{12} - \cdots - x_{1n} &= Y_1 \\
X_2 - x_{21} - x_{22} - \cdots - x_{2n} &= Y_2 \\
\vdots \qquad\qquad\qquad\qquad &\quad \vdots \\
X_n - x_{n1} - x_{n2} - \cdots - x_{nn} &= Y_n
\end{aligned}
\tag{7.1}
$$

Where $X_1, X_2, \cdots, X_n$ represent gross output of specific economic sectors of the economy, x_{ij} $(i, j=1, \cdots, n)$ represents the actual flow of goods and services from sector i to sector j; and Y_i $(i=1, \cdots, n)$ are the flows to final demand sectors (household consumption, investment, government, foreign trade, inventory).

The basic assumption made in the input-output analysis pertains to the relation between purchases of an endogenous sector (i.e., the x_{ij}) and the level of output of this sector (i.e., the X_j). Assuming a linear relationship (the appropriateness of this assumption for agriculture sectors is discussed elsewhere[2]), we obtain the equation in (7.2)

$$x_{ij} = a_{ij}X_j + c_{ij} \tag{7.2}$$

$$a_{ij} = x_{ij}X_j^{-1} \tag{7.3}$$

where a_{ij} and c_{ij} are parameters. For the empirical estimation which follows, the assumption is made that $c_{ij}=0$. The a_{ij} (commonly referred to as an input-output coefficient or technological coefficient) is derived from a single observation of the ratio between x_{ij} and X_j written as in (7.3). The input-output coefficient is the direct requirement of sector j upon sector i, per unit of output in sector j. For example, if industry purchased 25 billion dollars' worth of agricultural goods and total output for industry is 500 billion dollars, the corresponding input-output coefficient is 25/500, or .05, meaning that industry directly requires 5 cents worth of goods and services from agriculture per dollar of output in industry. Assuming $c_{ij}=0$, substituting (7.2) into (7.1) yields (7.4) in equation form, or (7.5) in matrix notation, where X is a vector of outputs from all sectors, A is a matrix of input-output coefficients and Y is a vector of final demand quantities.

$$\begin{aligned} X_1 - a_{11}X_1 - a_{12}X_2 - \cdots - a_{1n}X_n &= Y_1 \\ X_2 - a_{21}X_1 - a_{22}X_2 - \cdots - a_{2n}X_n &= Y_2 \\ \vdots \qquad\qquad\qquad\qquad &\quad \vdots \\ X_n - a_{n1}X_1 - a_{n2}X_2 - \cdots - a_{nn}X_n &= Y_n \end{aligned} \tag{7.4}$$

$$X - AX = Y \tag{7.5}$$

Hence, with specified final demands $Y_1, Y_2, \cdots, Y_n$ and constant input-output coefficients, equations (7.1) can be solved for the outputs $X_1, X_2, \cdots, X_n$. The resulting equations are given in (7.6). The A_{ij}'s (commonly referred to as interdependence coefficients) are elements of the inverse matrix $(I-A)^{-1}$ with the value of X expressed in the matrix notation of (7.7).

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[2] See Earl O. Heady and H. O. Carter, "Input-Output Models as Techniques of Analysis for Interregional Competition," *Jour. Farm Econ.*, Vol. 41; H. O. Carter and Earl O. Heady, *An Input-Output Analysis Emphasizing Regional and Commodity Groups of Agriculture*, Iowa Agr. Exp. Sta. Bul. 469; Earl O. Heady and John A. Schnittker, "Application of Input-Output Models to Agriculture," *Jour. Farm Econ.*, Vol. 39.

$$
\begin{aligned}
X_1 &= A_{11}Y_1 + A_{12}Y_2 + \cdots + A_{1n}Y_n \\
X_2 &= A_{21}Y_1 + A_{22}Y_2 + \cdots + A_{2n}Y_n \\
&\vdots \\
X_n &= A_{n1}Y_1 + A_{n2}Y_2 + \cdots + A_{nn}Y_n
\end{aligned} \tag{7.6}
$$

$$X = (1 - A)^{-1}Y \tag{7.7}$$

The interdependence coefficients (A_{ij}'s) represent the direct and indirect requirements upon sector i for a one-unit change in the amount of goods delivered to final demand by industry j. This characteristic makes the method pertinent to relationships among regional and industrial sectors, since both the indirect and direct effects of change are reflected among both sectors. Equations (7.1) through (7.4) represent the descriptive component, while equations (7.5) through (7.6) represent the analytical quantities of the input-output model. A simple model within the above general framework suggests the growth manner of interdependence of agriculture in aggregate with nonfarm sectors.[3]

We now turn to an input-output model from 1949 data emphasizing regional stratification of agriculture. It emphasizes the small extent to which the nonfarm sector now depends on agriculture and the fairly elaborate extent to which certain farm sectors depend on the former.[4] This model includes 12 agricultural sectors, a crop or primary sector (sectors 1 to 6) and a livestock or secondary sector (sectors 7 to 12) for each of the six geographic regions shown in Table 7.2. It includes 8 industrial or nonfarm sectors, with aggregation to emphasize sectors that furnish inputs for, or process products from, agriculture. The objectives of the study include describing relationships between agriculture and certain components of the nonagricultural economy. Industry aggregation

TABLE 7.2

COMPOSITION OF AGRICULTURAL REGIONS BY STATES

Region 1	Region 2	Region 3	Region 4	Region 5	Region 6
Maine	Ohio	Va.	N.Dak.	Mont.	Ariz.
N.H.	Ind.	W.Va.	S.Dak.	Idaho	Wash.
Vt.	Ill.	N.C.	Nebr.	Wyo.	Oreg.
Mass.	Wis.	S.C.	Kans.	Colo.	Calif.
R.I.	Mich.	Ga.	Okla.	N.Mex.	
Conn.	Minn.	Fla.	Tex.	Utah	
N.Y.	Iowa	Tenn.		Nev.	
N.J.	Mo.	Ala.			
Pa..	Ky.	Miss.			
Del.		Ark.			
Md.		La.			

[3] G. A. Peterson and Earl O. Heady, *Application of an Input-Output Analysis to a Simple Model Emphasizing Agriculture*, Iowa Agr. Exp. Sta. Bul. 427.

[4] See Heady and Schnittker, *op. cit.*, and Schnittker and Heady, *Application of Input-Output Analysis to a Regional Model Stressing Agriculture*, Iowa Agr. Exp. Sta. Bul. 454.

is based mostly on a detailed study of the United States economy made by the Bureau of Labor Statistics for 1947.[5] The industry sectors are:

Sector 13. Industries processing the products of primary agriculture, chiefly for food use, but including livestock feeds as by-products.
Sector 14. Industries processing the products of primary agriculture, chiefly for nonfood use.
Sector 15. Industries processing the food products of secondary agriculture.
Sector 16. Industries providing machinery, machine services, fuel and oil to all sectors of the economy.
Sector 17. Industries furnishing fertilizers, seeds and other supplies to agriculture, as well as many products to other sectors.
Sector 18. All other industries, including most services and transportation and merchandising.
Sector 19. Foreign trade.
Sector 20. Government.

In the simple model, intersector flows for agricultural regions were computed only for primary crops. Data on feeder stock were inadequate; all secondary livestock products were treated as if they went directly to sector 15. Although there were blanks in the table of input-output coefficients, there are none in the table of interdependence coefficients, however, because interrelationships are expressed both directly to a sector and indirectly back through other sectors.

Interdependence Coefficients

The interdependence coefficients computed for the model outlined above are included in Table 7.2. These quantities are equivalent to the A_{ij} values shown in the inverse matrix of (7.7) and the equations of (7.6). If put in matrix form and multiplied by the 1949 direct consumption of each of the 20 sectors, the product provides the output of the producing sectors. In the conventions of input-output literature, these coefficients might be interpreted as indicating the change in output of one producing sector associated with a *dollar's worth* of change in final demand (direct consumption) for the output of any other sector. However, we prefer to interpret the quantities shown as the average amount of product in a particular sector associated, in 1949, with each *dollar's worth* of product consumed directly from each other producing sector. In this vein, we do not suppose that the "fixed-mix" representing output of one sector will be projected into the future as national income increases. Neither do we suppose that the technical coefficients will remain constant as demand for the product of any one sector increases. Although

[5] See U.S. Dept. of Labor, *Industry Classification Manual for the 1947 Interindustry Relations Study*, Washington, D.C., 1953, (Mimeo.); and *Interindustry Flow of Goods and Services of Origin and Destination*, 1947, Washington, D.C., 1952.

TABLE 7.3

Interdependence Coefficients Between the Final Bill of Goods and Net Outputs for 1949

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Primary (Crop) Agriculture Sectors						Secondary (Livestock) Agriculture Sectors						Industry Sectors							
Sector No.	Reg. 1	Reg. 2	Reg. 3	Reg. 4	Reg. 5	Reg. 6	Reg. 1	Reg. 2	Reg. 3	Reg. 4	Reg. 5	Reg. 6	Crop-food products	Nonfood crop products	Livestock products	Machinery and fuel	Miscellaneous supplies	All other products	Foreign trade	Government
1	1.024	.002	.002	.001	.001	.002	.301	.003	.006	.003	.002	.005	.021	.007	.032	.001	.009	.002	.006	.003
2	.010	1.037	.007	.006	.007	.007	.034	.401	.017	.010	.012	.023	.068	.068	.137	.008	.023	.011	.040	.016
3	.008	.006	1.020	.005	.006	.006	.018	.009	.424	.009	.008	.015	.058	.108	.040	.009	.013	.010	.073	.016
4	.008	.006	.006	1.032	.007	.006	.018	.009	.014	.485	.020	.026	.058	.057	.067	.008	.017	.009	.046	.021
5	.002	.002	.002	.001	1.038	.002	.006	.003	.004	.003	.041	.005	.021	.007	.020	.002	.006	.002	.006	.005
6	.004	.003	.003	.002	.003	1.013	.018	.006	.013	.007	.006	.317	.066	.020	.023	.003	.009	.004	.017	.007
7	.076	.001	.001	.001	.001	.001	1.024	.001	.002	.001	.001	.002	.007	.005	.101	.001	.003	.002	.005	.003
8	.005	.081	.004	.003	.004	.004	.009	1.034	.006	.005	.004	.007	.022	.020	.331	.005	.008	.008	.019	.010
9	.001	.001	.037	.001	.001	.009	.002	.001	1.016	.001	.001	.002	.006	.007	.076	.001	.002	.002	.006	.003
10	.002	.002	.002	.060	.002	.002	.004	.002	.003	.030	.003	.004	.010	.002	.123	.002	.003	.003	.009	.004
11	.001	.001	.001	.001	.082	.001	.001	.001	.001	.001	1.037	.001	.004	.005	.040	.001	.001	.001	.003	.002
12	.001	.001	.001	.001	.001	.035	.002	.001	.001	.001	.001	1.012	.005	.004	.053	.008	.001	.001	.003	.002
13	.031	.016	.018	.014	.015	.016	.256	.082	.177	.092	.068	.195	1.020	.034	.103	.013	.020	.021	.061	.022
14	.027	.025	.023	.021	.025	.023	.039	.025	.033	.025	.024	.032	.081	1.024	.026	.046	.037	.049	.119	.031
15	.012	.011	.010	.009	.011	.010	.020	.011	.016	.002	.011	.017	.052	.044	1.012	.014	.019	.021	.050	.026
16	.164	.170	.136	.146	.185	.161	.113	.110	.109	.113	.126	.108	.091	.073	.089	1.042	.062	.067	.292	.066
17	.145	.087	.106	.048	.052	.082	.062	.044	.058	.033	.034	.041	.044	.043	.036	.033	1.018	.024	.097	.021
18	.467	.466	.408	.399	.477	.424	.462	.393	.431	.396	.409	.414	.449	.406	.368	.648	.546	1.157	1.022	.482
19	.028	.025	.021	.021	.025	.023	.045	.026	.035	.026	.025	.036	.112	.070	.034	.033	.042	.043	1.052	.089
20	.165	.155	.114	.125	.154	.146	.135	.114	.113	.113	.121	.120	.143	.163	.109	.165	.165	.188	.236	1.088

the "fixed-mix" restriction is not always a serious limitation when emphasis is on industry, the problem is more difficult for agricultural sectors specializing in products with definite inter-regional differences in income elasticities of demand.

Given the model employed, the important elements affecting farm sectors are magnitudes of final demand for the products of industries processing the products of agricultural sectors. The figures presented represent inter-industry relationships for a given point in time, 1949. The coefficients in the table show the amount of output in the row sector per dollar's worth of final demand for the products of the column sector. (The table is the matrix of interdependence coefficients such as the matrix of A_{ij}'s in (7.6). The column headings indicate the Y_i elements in the Y matrix and the row-stub headings represent the X_i values of the X matrix.) Thus a dollar's worth of final demand for crop-food products, sector 13, is associated with an output of only \$.0211 in sector 1 (the Northeast), and \$.0655 in sector 6 (the Pacific Coast), where a large proportion of fruits and vegetables move into sector 13, processing, and then to final demand. The interdependence coefficient of sector 13 with sector 5 (crop production in the Mountain states) is only \$.0207. The bulk of crop production there consists of forage crops, which move to livestock in the same region.

The sum of the first six rows in column 13 is only .291, pointing up, in numerical terms, the existing situation in respect to the farmer's share of the consumer's dollar spent for crop-food products. Each dollar of final demand or household consumption of products in sector 13 requires only a 29-cent output by all agricultural crop sectors. The large interdependence coefficient, 45 cents (column 13, row 18), indicates that each dollar's worth of consumption of products in sector 13 is associated with a large output by sector 18, which includes mainly transportation and merchandising services.

A dollar of final demand for sector 15 or livestock products is associated with a *total mix value* of 72 cents (the sum of rows 7 to 12 in column 15) for the six secondary agricultural sectors. The fact that this figure is much greater for livestock than for crops indicates that a much larger proportion of the consumer's dollar, for livestock products, reaches the farmer. More than 33 cents of the 72-cent total is drawn from the Cornbelt where the main farm product, livestock, provides the major part of the pork, beef and milk consumed by the nation. The next largest interdependence coefficient is for sector 10, the western portion of the hog-raising and beef-feeding area, which provides a considerable amount of beef processed directly from the range. Although livestock is the important product of sector 11, most of this is range beef and sheep, which moves to the feedlots of sectors 8 and 10, rather than directly to processing, sector 15.

The interdependence coefficients of sector 15 on regional crop-producing sectors show the largest coefficient again to be for the Cornbelt (sector 8). A dollar's worth of final demand for the product of livestock processing in sector 15 was associated in 1949 with a 14-cent output of crops in sector 8; since most of the Cornbelt crop product (sector 2) moved to livestock in the same region (sector 8), and then into the livestock-processing industry (sector 15). A dollar's worth of final demand for products in sector 15 (livestock at retail) required a Cornbelt crop output greater than the livestock output in any other region.

Based on the model, final demand for the product of industrial sector 18 has little relationship to the output of agricultural sectors. The coefficients range from .0011 for secondary output in the Intermountain states (sector 11) to .0160 for primary output in the Cornbelt. In contrast, however, final demand for products of agricultural sectors required a much greater output from sector 18. These quantities (row 18, columns 1 to 12) range from .3928 for secondary products in the Cornbelt to .4768 for primary products in the Intermountain states. Similarly, while sector 16 (machinery and fuel) final demand bears only a trivial relationship to output of agricultural sectors (column 16, rows 1 to 12), the opposite is not true. One dollar of final demand for crop or primary agricultural products in sector 5 (the Intermountain states) was associated with an 18-cent output in the machinery and fuel sector. The figure was 14 cents for the Southeast (sector 3), where more of the work is done by man and horsepower and machine inputs per dollar of crop output are generally lower than for other regions (row 18, columns 1 to 6).

Interindustry Dependence

We now summarize a second regional input-output model where 1954 agriculture has been divided into the 10 regional sectors indicated in Table 7.4, for comparison against three nonfarm sectors—namely, industries processing farm products, industries furnishing inputs to agriculture and all other industries.[6] The agricultural processing industry is, of course, highly dependent on agriculture. In Table 7.4, a one dollar increase in demand for the product of this sector (I) is associated with a 59.1 output (the sum of the first 10 rows under column I) in all 10 agricultural sectors, with 25 percent or 15.3 cents of this from the Cornbelt and only 4 percent, or 2.3 cents, from the Delta states.

But the more significant figures in interdependence are those of agricultural furnishing (II) and other sectors (III) with agriculture. All agricultural sectors have demand on sector II greater than 31 cents for each dollar of output in the regional farm sectors—the largest being 55.2 cents for the Northeast and the smallest being 31.2 cents for the Pacific states. The interdependence, per dollar of output, is even greater of farm sectors on the "other" (III) sector, amounting to more than 42 cents for all farm sectors and ranging from 56.2 cents in the Northeast to 44.4 cents in the Pacific states. In contrast, for each dollar of output, the agricultural furnishing sector draws no more than 3 cents from any farm sector, with the predominant magnitude being less than a single cent. Each dollar of

[6] See Heady and Carter, *op. cit.* and Carter and Heady, *op. cit.*

TABLE 7.4

INTERDEPENDENCE COEFFICIENTS, UNITED STATES ECONOMY, 1954,* AGGREGATION OF REGIONS AND SUBDIVISIONS OF INDUSTRY

	Agricultural Regions										Industry		
	1 North-east	2 Corn-belt	3 Lake States	4 Appal. States	5 South-east	6 Delta States	7 S. Plains	8 N. Plains	9 Mount. States	10 Pacific States	I Agr. processing	II Agr. furnishing	III All other
1	1.295	.002	.002	002	.002	.002	.002	.002	.002	.002	.063	.005	.003
2	.019	1.419	.010	.023	.009	.049	.014	.010	.009	.008	.153	.030	.009
3	.006	.004	1.436	.003	.003	.003	.003	.003	.003	.003	.068	.009	.004
4	.006	.002	.002	1.306	.002	.002	.002	.002	.002	.002	.053	.006	.003
5	.002	.002	.002	.002	1.259	.001	.002	.002	.002	.001	.038	.005	.002
6	.002	.001	.002	.001	.001	1.193	.001	.002	.001	.001	.023	.005	.001
7	.003	.010	.002	.007	.005	.002	1.211	.012	.002	.013	.040	.007	.002
8	.011	.039	.013	.003	.003	.004	.019	1.447	.006	.015	.060	.009	.003
9	.003	.012	.007	.002	.002	.002	.038	.059	1.410	.035	.043	.005	.002
10	.003	.002	.002	.002	.002	.002	.002	.003	.002	1.186	.063	.005	.003
I	.040	.032	.033	.029	.027	.026	.030	.037	.031	.028	1.199	.071	.060
II	.552	.335	.373	.370	.365	.329	.358	.369	.326	.312	.234	1.372	.088
III	.562	.549	.502	.454	.431	.422	.477	.610	.486	.444	.461	.801	1.610

* Each entry shows the amount that the gross output of the sector named at the left would change, given a change of one dollar in the final demand for products of the sector named at the top.

final demand for product of sector III requires less than a cent of output from any farm sector.

Quite obviously, even under the limitations of mathematical form in the model, the "influence of agriculture per se on general economy" is minor but the interdependence of agriculture with national economy is major. The proportions are so clear that agricultural policy to serve as backfire against the rolling flame of national economic development at the stage of United States growth cannot be effective in the long run.

REGIONAL ADJUSTMENT NEEDS AND POTENTIAL

Agriculture of all regions is caught up in the pressures of factor prices, technological change, alternative employment opportunity and preferences and aspirations of consumers which will change farming structure. Economic development will, in the decades of 1960 through the 1980's, cause greater adjustment in labor input, relative capital employment and farm size in some regions than in others, depending on the extent to which market imperfections and institutional restrictions have impeded balance in use of, and returns to, agricultural resources as compared to those of nonfarm sectors. Some sectors of agriculture have long had returns to human resources which were mere pittance of factor returns in other sectors and of income against the American standard of living. As illustration of this point, we select 1950 for basic income comparisons of farm production regions in the United States. At this point in time, U.S. agriculture had just emerged from the most profitable period in history, important nonfarm recessions had been unimportant and nonfarm employment opportunity had been great. Existing prices mainly reflected consumer preferences apart from price supports and surplus build-up.

Figure 7.2 indicates geographic average return to operator's labor of commercial farms in 1949, after returns were imputed at market rates to other resources.[7] Over the major expanse of space and population, return for operator labor was less than $1,500 as compared to labor income (excluding all capital return) of $2,544 per employed nonfarm person in 1949. In large areas of the South and East, operator labor income was less than $500, being negative on the computational basis, in the mountain areas stretching from Tennessee through Pennsylvania. By 1960, the relative position of agriculture, labor income of farms compared with nonfarm sectors, had deteriorated even more over the nation, but the relative rank of regions largely still paralleled that of Figure 7.2.

Variance in income among regions is related closely, but not entirely, to capital and total inputs used per farm and per unit of labor. This fact

[7] From Earl O. Heady and E. G. Strand, "Efficiency Within American Agriculture," *Jour. Farm Econ.*, Vol. 37; and E. G. Strand, Earl O. Heady and J. A. Seagraves, *Productivity and Resources Used on Commercial Farms*, USDA Tech. Bul. 1128. Farms included were the 3.7 million commercial farms (out of 5.4 million total farms) with 97.5 percent of total value of farm products sold in 1949. Included are farms with sales of $1,200 or more and excluding part-time, residential and abnormal farms.

is illustrated by comparison of Figure 7.2 with 7.3, the latter indicating regional averages of annual inputs per farm, with capital expressed on a service rather than on an investment basis. Input per farm is greatest in areas of highly specialized agriculture such as dairy and fruit production in the Southwest and specialized poultry production on the Eastern Seaboard. It is lowest in cotton and mountain areas where institutional and related factors have caused the elasticity of capital and labor supply to individual farms and regional aggregates to be low. Highly specialized farming areas are those already geared most closely with factor and commodity markets of the nonfarm economy. Regions with low capital per farm, and large use of labor relative to capital, are those where the factor markets for agriculture have been highly apart from those of the nonfarm economy.

With increased public investment in education and vocational guidance, rural development and depressed area legislation, connection between factor markets of farms and nonfarm sectors will be greater in those areas of lowest farm and operator incomes. Industrial development, complemented with increased communication and knowledge, as pointed out in Chapter 4, also will pull in this direction. As it occurs, and input of labor declines still further, interdependence of agriculture with national economy will grow even tighter. Without these price and communication links between factor markets, however, great disparity can still exist between returns of farm and nonfarm resources.

This point is well illustrated in two broad regions of Figure 7.2. In the Southwest, largely California, where industrialization has been at a rapid rate, and labor and capital markets for agriculture are closely related to those of other sectors, a highly commercialized agriculture with favorable factor returns has developed. In the Southeast, where industrialization also has been at a fairly high rate, certainly as compared to the Plains and western Cornbelt, similar development in commercialization of farming has been highly absent. Farming in much of the old cotton and sharecropping areas is but little advanced beyond that of India in technology, and differs by only a small margin in the proportion of labor in the input mix. Capital supply to these farmers is of low elasticity, causing it to be high in price and rationed closely against tangible equity; labor is lacking in nonfarm connection and is of low supply elasticity to agriculture, thus being priced at low levels. As much as any, this is the blighted area of American society. But the rate of adjustment can and will be high. Given the practical elements that cause labor markets to work efficiently—education, employment services, job communication and transport foods—this segment of agriculture can become much more closely attached to the national economy and its growth rewards.

Sample Marginal Resource Productivities

Differentials in resource productivities for scattered segments of U.S. agriculture at about the same time can be illustrated from estimation of resource productivities from farm samples. Samples drawn from the

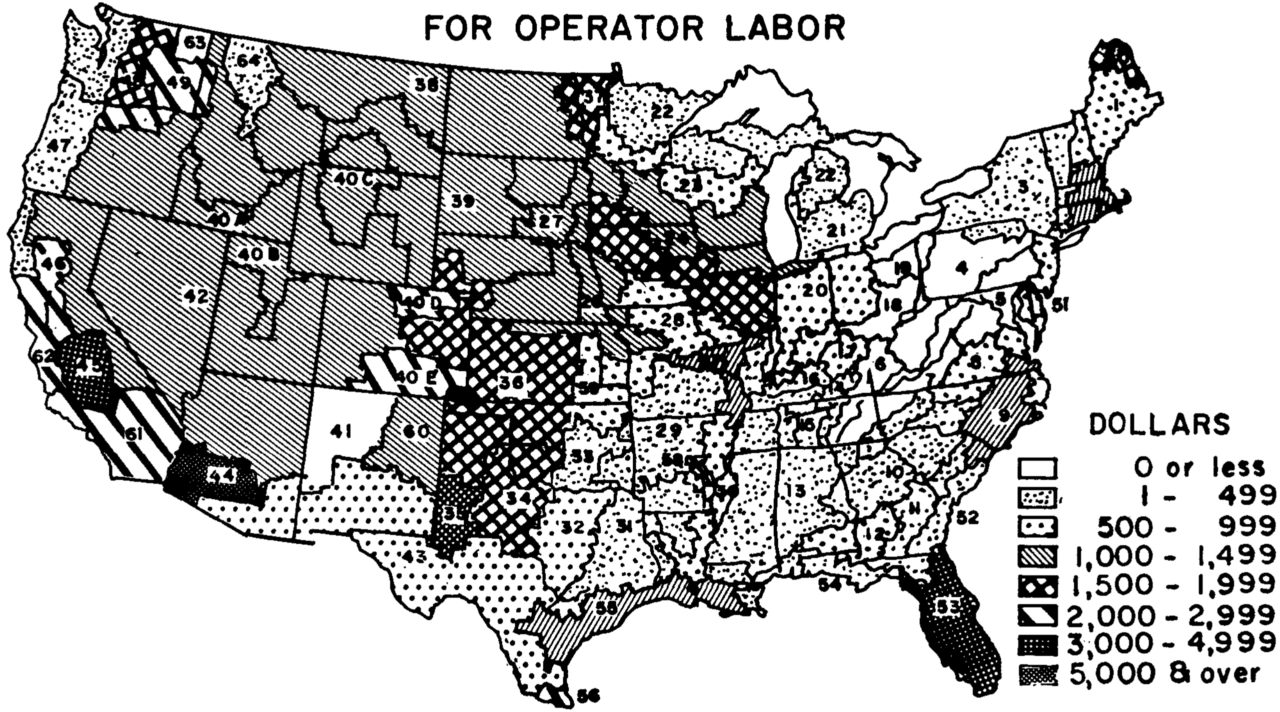

Fig. 7.2. Residual Operator Labor Income by Productivity Region, 1949. Commercial Farms Only.

commercial wheat area of Montana, the productive Clarion-Webster soil area of north central Iowa and the Piedmont area of Alabama represent a wide range of farming but do not fall at the extremes of commercialization and income mentioned above. The Alabama sample represents farming above the average of the general geographic region.[8] Two production functions of the form in (7.8) were fitted to the sample observations of each area, one for crop production and one for livestock production.

$$Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3} \tag{7.8}$$

However, the livestock function includes only X_1 and X_2 input categories where X_1 refers to annual labor input in months, X_2 refers to annual input of all capital services in dollars and X_3 refers to cropland input in acres where Y is output measured in dollars. Marginal and gross average productivities have been computed for all three samples and are presented in Tables 7.5.

The particular form of function has limitations in refined quantitative predictions, but allows "mean comparisons for diagnostic purposes."[9] Marginal productivities of labor drop to low levels at mean input, since greater use of this resource against zero increase of other resources would add small product. Yet a considerable difference in marginal labor productivity did exist in 1950 between the northern and southern samples, largely because the amount of capital and technology per farm and worker was at a much lower level in the Alabama sample. The average productivities, which reflect and are related to the marginal productivity of all units of resources, differ even more and likely are more important for the comparisons. While value productivities in all areas would have been smaller a decade later, similar relative difference prevailed. Quite obviously, large increase in inputs per farm and laborer are necessary to bring returns in the Alabama area to the level of Montana, and even more to the level of nonfarm opportunity since the other two areas also lag in this respect.[10] In qualitative fashion, the data indicate differences in extent of adjustment to resource prices and economic development which exist over U.S. agriculture, with an even greater range existing for the total of the industry. They also suggest the differential magnitude of adjustment necessary if farms in all regions are to be brought to levels of resource returns approaching those of the nonfarm economy.

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[8] For details of this study, see Earl O. Heady and R. Shaw, "Resource Returns and Productivity Coefficients in Selected Farming Areas," *Jour. Farm Econ.*, Vol. 36.

[9] Cf. Earl O. Heady and John F. Dillon, *Agricultural Production Functions*, Iowa State University Press, Ames, 1961. Chaps. 1 to 4.

[10] The low productivity of capital for crops in northern Iowa may be due to either (1) sample variance or (2) the fact that farmers on the average used so much machinery (machine services dominate the input category) that it had extremely low productivity. Farms in the area had invested in machinery beyond production levels and to consumption levels for matters of convenience and avoidance of drudgery, etc.

VALUE OF TOTAL INPUT

Per Commercial Farm, by Productivity Regions, 1949

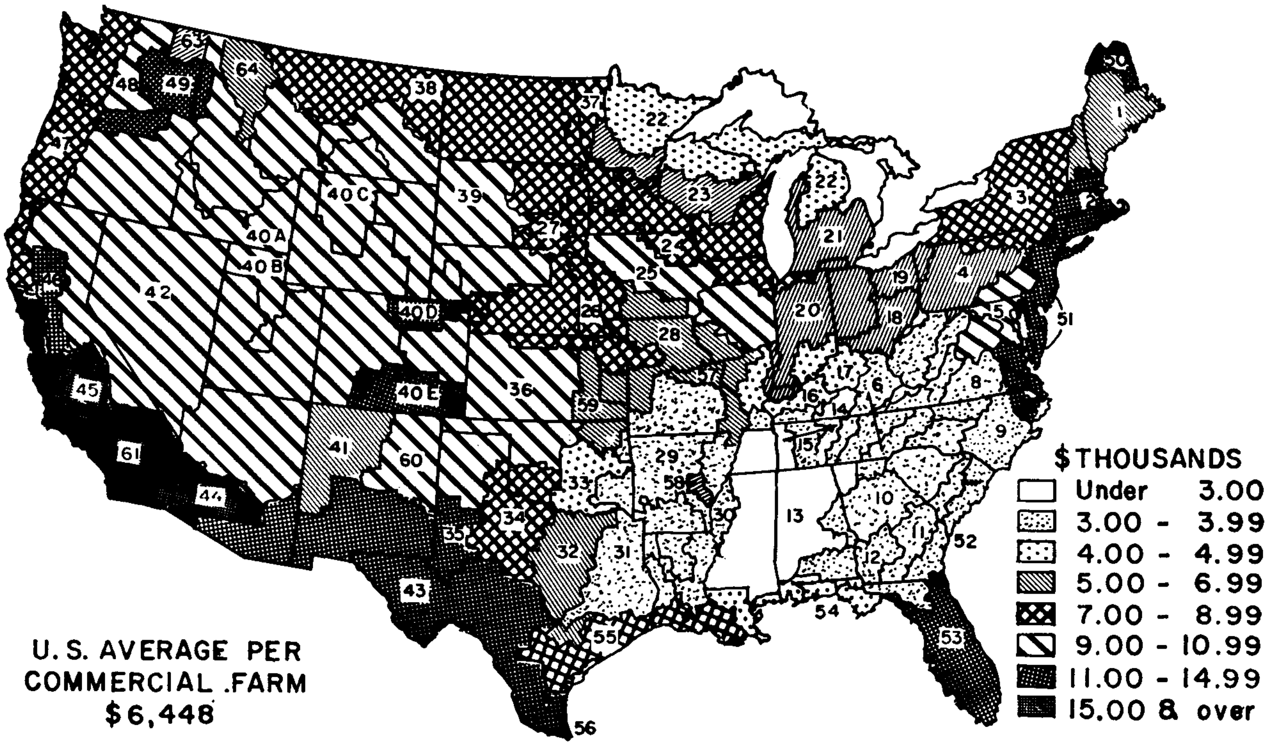

Fig. 7.3. Value of Total Inputs for Commercial Farms, 1949. Annual Services of Land, Labor and Capital.

TABLE 7.5

PRODUCTION ELASTICITIES AND MARGINAL AND AVERAGE PRODUCTIVITIES FOR FARM SAMPLES, 1950

Item	Montana	N. Iowa	Alabama
Crop Function			
Value of a (log)	.595	1.273	.979
Value of b_i			
Labor	.039	.088	.319
Land	.503	.912	.385
Capital	.580	.165	.463
Marginal products			
Labor ($/acre)	11	47	21
Land ($/mo.)	62	68	40
Capital ($/$)	2.39	.65	1.15
Gross average elasticities			
Labor ($/acre)	22	51	56
Land ($/mo.)	1,559	905	127
Capital ($/$)	4.11	3.94	2.39
Livestock Function			
Value of a (log)	.276	.359	.737
Value of b_i			
Labor	.084	.077	.233
Capital	.937	.907	.743
Marginal products			
Labor ($/mo.)	114	131	89
Capital ($/$)	1.27	1.06	.97
Gross average productivity			
Labor ($/mo.)	1,351	1,694	378
Capital ($/$)	1.36	1.11	1.31
Mean input ($)	30,634	22,718	2,734
Mean output ($)	14,741	16,710	1,694
Labor (mo.)	20.3	17.5	13.9

Classes of Farms

Further indication of the extent of adjustment in structure of agriculture by region and class of farm is indicated in Table 7.6. It shows the percentage of commercial farms (excluding part-time and residential farms) in each geographic region with gross value of sales less than $5,000. Given the per capita income and the high standard of living spread widely over the society, a farm with gross value of sales under $5,000 provides a substandard level of family income and returns to resources. From the gross value of sales must be subtracted annual ex-

TABLE 7.6

PERCENT OF FARMS BY REGIONS WITH VALUE OF SALES LESS THAN $5,000 IN 1954

Region	Percent of All Farms in Region	Percent of U.S. Farms With Sales Less Than $5,000
New England	39.5	1.0
Mid Atlantic	43.4	3.8
E. N. Central	49.3	16.1
W. N. Central	44.7	19.1
S. Atlantic	76.0	19.6
E. S. Central	87.4	21.5
W. S. Central	65.2	13.4
Mountain	33.9	2.9
Pacific	33.3	2.6
U.S.	58.4	100.0

penses, leaving a net for family living and resource returns much smaller than the $4,732 annual wage of labor in all manufacturing industries in 1954.

Adjustments for prices of consumption items need to be made, of course, to indicate relative differences in real income. However, it also must be remembered that gross sales of $5,000 not only requires deduction of annual expenses but also the remainder represents return to capital as well as labor. Somewhat more than 87 percent of all farms in the East South Central region had value of sales less than $5,000 in 1954, while 76.0 percent in the South Atlantic fell in this category. In contrast, the Mountain and Pacific regions had only 33.9 and 33.3 respectively. The number of farms in the Pacific region with value of sales less than $5,000 was only 2.6 percent of the U.S. total. The corresponding figure for the East South Central region was 21.5 percent.

The magnitude of $5,000 gross sales might seem high at first glance. But certainly it is not when we are reminded that it is gross income and that the median per family net income of the nation was $5,600 in 1960 while mean family income was $6,900; or that net income of skilled wage workers, with adjustment for price level, exceeds even this gross quantity. But even in 1959 over 25 percent of all commercial farms in the U.S. had gross value of sales less than $5,000. Over 63 percent of all farms in the East South Central region and 46 percent in the South Atlantic had value of sales less than $2,500 in 1954. In contrast, the percentage was only 20 percent in the West North Central, 17 percent in the Mountain and 13 percent in the Pacific regions.

These data suggest magnitudes of adjustment in farm number, size and resource structure required if farm family income is to be brought to levels consistent with the magnitude of general living standards and national income of the United States. A "simple" goal (lacking refinement in economic definition and marginal quantities) of commercial farms which produce more than $5,000 in gross sales per annum is hardly an unrealistic and fantastic goal, given the degree of economic development and mean per capita income for the nation.[11] Attainment of this goal will not be attained by price and production policy which restrains supply to match demand growth. Too many of the farms in the above categories have such small volume and so few resources that a policy boosting prices by a fourth would still leave them with incomes far below our simple standard. To an important extent, major income improvement for these classes of farms must come from farm enlargement and increased proportion of capital with labor for those that remain. Over the longer run, for younger and flexible persons, many will need off-farm employment opportunity if they are to find full expression of their abilities and opportunity for living standard and consumption consistent with the U.S. norm.

The problem of adjustment is most complex in the regions where need is greatest, not only because of the number of small farms with inadequate resources but also because institutional forces and factor markets are more restraining than in areas where the proportion of farms with low volume is smallest. Too, it is in these same areas that social overhead capital is too low to allow production of human resources most adaptable to employment opportunities under growth. In any case, price policy and supply management cannot solve this problem of low volume and inadequate resources for all families falling in this category. It is misleading for farm spokesmen to lead farm families in believing so. Even more, it turns the hope of people in misleading directions, with longer-run impact on lives and well-being of farm children and younger persons. Needed more, or simultaneously, is improved education, training and employment services and job opportunities which allow those who cannot acquire adequate resources, if even because of restraints in land area and space as farms are enlarged, fuller opportunity for expression of their abilities and living standard consistent with the developing status of the American economy.

REGIONAL ADJUSTMENT IN STRUCTURE

The income figures cited above indicate one reason why adjustment of agriculture to a structure more consistent with the wealth and economic development of the nation would cause differential change among regions. Aside from these phenomena, changes in the structure of agriculture to conform with economic growth would be of equal nature and

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[11] Part-time farms, on the basis of census definition, have been excluded from the classifications in Table 7.6. However, some commercial farms in these groups have family members receiving income from off-farm sources while other units have low income because they are operated by beginning farmers, older people in semi-retirement and a normal number of persons of poor health. Hence, not all farms with gross value of sales of $5,000 would need elimination if we were to move towards the "simple" goal mentioned in the paragraph.

magnitude only under certain conditions. Changes in production and price functions, and any other quantities relating to supply of factors and commodities, would have to be of the same relative magnitude in all regions. Degree of economic development, providing employment opportunities and factor returns in nonfarm uses, would have to be of similar magnitude for each region. Finally, rate of growth in population and consumer demand would have to be the same at all locations so that relative advantage from the side of commodity prices and space would be the same. Under this condition, supply functions, production possibilities and comparative advantage would remain relatively the same for all agricultural regions. Adjustment in resource inputs and product outputs then would be of similar nature for all regions. With supply increase exceeding demand increase, the same proportion of resources would need to leave agriculture in each region, and similar pattern of change in farm size and numbers would occur. The commodity mix of the nation would contain about the same proportions of product from the various spatial and commodity components of agriculture as in the past. But the latter would be possible only if consumers desired all food in "fixed-mix" proportions, meaning that they would not shift among commodities as their incomes increased as reflected by the demand elasticities in Chapter 6.

This uniformity in economic development of agriculture and industry would ease and simplify social adjustment. Each community would have relatively the same increase in investment and industry, tax source and public services, employment and occupational shift. However, development has never been characterized by this spatial "evenness." Even in days of an agricultural nation and westward movement, it was not true. Not all communities can expect equal rates of growth, and therefore equal pleasure or pain in economic adjustment. In the first place, growth of the industrial and consumer sectors does not take place evenly over space, due to differential opportunity of different locations as they are reflected in supply price of commodities and resources such as raw materials, climatic elements, transportation and others. With orientation of industry to locations with lowest supply price for such elements of production, population and consumer growth is oriented similarly, thus causing the relative demands for food and other commodities to shift in similar fashion in respect to space. Demand for labor resources and job opportunities thus grows differentially among communities, drawing surplus resources more readily from farms or other "oversupplied" industries in some localities. Even without this shift of industrial and consumer pattern over space, differential demand growth between general commodity groups, and within the food category itself, comes about as per capita income increases.

Since agricultural regions differ in their endowment of soil, climate and other resources of nature, they respond differentially to increased resource inputs. They also respond differentially with new forms of capital representing technological advance. Supply functions of greater differentials in elasticity arise, even in the absence of new technology, as inputs are extended and ranges of the production function with greater or lesser elasticity, depending on nature's endowment, are reached. Hence, comparative advantage among regions changes, and change in the spatial and commodity mix of farm products occurs, with resources in some regions rewarded more or less handsomely than those of others.

This shift also would occur even in the absence of technical change in agriculture. The latter, along with growth in per capita income and shift in consumer preferences for foods, provides the major force in causing the relative advantage and structure of agriculture to differ under economic development. New technology does not affect, or result in, the same increase in marginal resource productivities in all regions. Again this is true because different regions are endowed variously with natural resources. A new seed variety has great productivity in an area of warm climate and long growing season, but not where the magnitude of these natural resources is small. Fertilizer, perhaps in interaction with the new seed variety, has greater productivity where nature's input of moisture or a complementary element is large. Large-scale machinery is better adapted for plains than for mountainous regions. But further, economic development and alteration of factor prices may cause mechanization to become more profitable in the one region, thus causing the region to grow in supply function and comparative advantage relative to another. With labor low in price relative to capital in another region, labor technology may be more economical than machine technology, with crops such as coffee remaining on the mountainsides and away from the plains. But if labor rises sufficiently in relation to capital, machine technology may prevail, with the crop moving from the mountains to the plains. This complex of forces has not been unimportant in causing cotton to shift from the Southeast to the Southwest.

Implication in Policy

We have mentioned a second reason why policy, particularly that designed to make income compensation to current farmers, needs to orient itself to change in structure of agriculture implied by economic development. Policy which attempts to fit all regions into the same mold may prevail momentarily. But over the decades, pressure will increase it to break out of the mold. If policy is designed to provide market power, income stability and similar elements possessed by other sectors, it needs to consider variables and forces leading to change in supply structure and comparative advantage among regions. It needs to recognize that these policy elements in the hands of other economic sectors do not eliminate change, or competition among sectors, in the long-run. Even where other sectors have been given opportunity in the market or through legislation to attain certain economic goals, the mechanisms have not generally been to contain economic growth or employment opportunity to particular spatial pattern.

Space is, of course, more nearly a factor of production in agriculture. However, to the extent that farm policy is aimed mainly at putting agriculture on the same footing as other sectors in respect to market control and stability, opportunity for the industry to change its spatial concentration and configuration would not only be consistent with general policy but would allow greater rate of economic development. Where farm policy is mainly to provide temporary compensation for sacrifices growing out of progress and development, such as more food at lower expenditure for consumers but smaller revenue to producers, elements of policy which even allow step-by-step transition to new spatial pattern would be consistent with developmental opportunities and goals. This is in line with our earlier proposition—namely, that while farmers of this generation may believe compensation to be due them while they remain in farming, they do not hold equally that a structure of agriculture should be maintained to restrain and subsidize their children and grandchildren in agriculture, holding them apart from opportunity in other sectors of a growing economy. Finally, policy which tries to maintain an historic structure of agriculture is certain to be confronted with strong forces of the market tending to pull it apart, and, for the same reason, with inability of competing regional and commodity groups to obtain agreement on policy.

Regional Structure

With the progress of time and under upcoming national goals, the pricing system should be given greater opportunity to serve as a guide in resource allocation than has held true in the past decade. If for no other reasons, this should be accomplished to avoid tremendous build-up of surpluses with their heavy treasury costs and the image and stigma which served to embarrass agriculture as an industry. This does not mean that agriculture must be turned to the caprices of a stampeding market of pure competition and great short-run instability of income while other major segments of the economy are not so characterized. But while other sectors have self-administered and legislated mechanisms for assuring degree of stability and short-run destiny over their prices, they have not been able to circumvent the draw of the pricing mechanism as it represents consumer's desires, relative supplies of factors, technical change and the general shift of resources among commodity and factor mixes.

The extreme control over supply and price exercised by unions and railroads did not prevent a rapid substitution of air and auto travel for train transportation. The structure of the steel industry and the ability to manage supply and specify price did not prevent a relative substitution of aluminum produced by a competing industry. Neither did the motion picture industry, one not characterized by pure competition, have power to prevent consumers from substituting television for movies, thus bringing about a re-allocation of resources. At most, industries with monopolistic and oligopolistic market powers provide short-run stability to price, but do not and cannot prevent broader change and re-allocations of resources from occurring as the structure of consumer demand

and factor supply changes under development. Perhaps price policy of agriculture should be viewed in the same light, namely, to provide short-run stability but to allow and facilitate long-run adaptation of resources to broad changes in consumer demand, technology and factor supplies.

In this light, the spatial pattern of agriculture will be modified to correspond with differential change among regions in economic development and population, employment opportunities, technology and factor prices. Elements of both gradual and rapid change already have shown up in U.S. agriculture, causing its products to become more specialized to particular regions. From the *gradual pole* we have the Northeast and parts of the Middle Atlantic Coast where decline of land in farms has been relatively great, but over several decades. Land has shifted not only to industrial and urban uses, but also, and more important in terms of acreage, into forestry. A similar but somewhat less rapid shift has taken place in the Southeast. From the *rapid pole*, broiler production shifted quickly to specialized areas of the East and Southeast. Under economic development, it appears that shifts of this type will continue. Feed grains and wheat could become more centrally concentrated in those regions which now specialize in them. Feed-grain production could recede from east to west, leaving the central Cornbelt relatively more important than previously in total output. Wheat could recede back from the more arid regions of the Plains to the hubs of spring and winter wheat areas of greater comparative advantage in this crop. Cotton would shift, particularly with time and change in resource structure from pull of non-farm wage rates, to the West and areas most adapted to yield and mechanization.

These points can be illustrated with a model designed to examine the regional concentration of production, if production were to be brought into line with demand, and comparative advantage were to reign by regions. The first model presented applies to 1954 conditions in terms of technology and demand level. Brought to 1965 level, it specifies a somewhat larger acreage to be withdrawn from production, but the general configuration is somewhat the same. We deal only with feed grains and wheat in three models, and with these plus soybeans and cotton in a fourth. A later model is being developed to include technology and demand extended to a more future point in time.[12] We use a linear programming model since it suits the purposes at hand, namely, approximation of the acreage and location of land which would be removed from production to balance output against "requirements." Ideally, the analysis would include a system of demand curves and supply functions, related over regions to indicate equilibrium of price and quantities. However, the model employed serves for the "diagnostic purposes" at hand, although it has obvious limits for particular regions.

[12] For further details of the model, see Earl O. Heady and Alvin C. Egbert, "Programming Regional Adjustments in Grain Production to Eliminate Surpluses," *Jour. Farm Econ.*, Vol. 41; and Alvin C. Egbert and Earl O. Heady, *Regional Adjustments in Grain Production: A Linear Programming Analysis*. USDA Tech. Bul. 1241.

Downward adjustments in production to meet demand entail two types of input changes: (1) withdrawal of land and complementary inputs from grain production in extensive regions so that the geographic pattern of production would be consistent with restricted comparative advantages of various regions, and (2) maintenance of land in production but a lessening of other inputs or reduction of farming intensity in areas remaining in production of current crops. While we analyze only the first of these, we believe that this is the major adjustment involved and that the second would alter results only slightly.

Our concern in the first models is mainly with production of wheat and of feed grains (corn, oats, barley and grain sorghums), commodities of greatest burden in surplus storage. Because of the size of the empirical task, we attempt to determine which regions should continue to produce these grains and which should shift to other products to make annual output approximate annual "requirements" or disappearance of these products. The year 1954 serves, for the data presented, as the basis for relating output to requirements because the research was initiated soon after this date. Requirements are considered to be a "discrete" quantity. They represent disappearance of grain in 1954 adjusted for normal exports, livestock populations, and food requirements. We suppose, because we could only thus make the computational burden manageable, that requirements coefficients are constant within each region.

Three programming models (A, B and C), given first, represent, without inclusion of disposal activities or slack variables, coefficient matrices of 106×310 order. The United States was broken down into 104 producing regions, each with the three activities: feed grains, wheat for food and wheat for feed. Restrictions included land or acreage constraints for these crop activities in the 104 regions, plus two restrictions for total U.S. feed grain and food wheat demand. A fourth model reviewed (D), included more activities than 310 since soybeans and cotton also were included as competing crops. The procedure used considers the comparative advantage of different regions in producing food and feed grains. Our objective function in two models is that for minimizing the cost of meeting demand requirements. In two models, maximizing profits is the objective.

Model A. The objective function for this model is (7.9) where C_k is a subvector of per unit costs, containing n elements to represent costs of producing feed grains and wheat in the kth region; and X_k is a subvector of crop outputs, with n elements representing production levels in the kth region. In this case, c_{jk}, the unit cost of producing the jth crop in the kth region includes only the labor, power, machine, seed, fertilizer and related inputs for each grain. In other words, land rent is not included as a cost. Neither are farm overhead or fixed costs included.

$$\text{(7.9)} \qquad \text{Min.} f(X) = C_1X_1 + \cdots + C_kX_k + \cdots + C_rX_r$$

$$\text{(7.10)} \qquad x_{1k}p_{1k} + x_{2k}p_{2k} + x_{3k}p_{3k} \leq S_k$$

We have $r = 104$ regions and minimize (7.9) subject to the restraints in (7.10) where x_{1k}, x_{2k} and x_{3k} refer respectively to outputs of feed grains (corn, barley, oats and grain sorghums), feed wheat, and food wheat in the kth region and p_{1k}, p_{2k} and p_{3k} stand for the per unit land inputs for these activities in the kth region, while S_k is a vector of acreage restrictions in this same region. The total programming matrices include 104 inequalities such as those in (7.10). The restrictions in S_k are set equal to the largest acreages devoted to feed grains and wheat in the previous 8 years when production control was not in effect.

In addition, to these 104 inequalities to represent acreage restraints, there are two *discrete* demand restrictions,

$$x_{11} + x_{21} + x_{12} + x_{22} + \cdots + x_{1k} + x_{2k} + \cdots + x_{1r} + x_{2r} = d_1 \tag{7.11}$$

$$x_{31} + x_{32} + \cdots + x_{3k} + \cdots + x_{3r} = d_2. \tag{7.12}$$

In (7.11), a national "demand" restriction for feed grains, the coefficient of all x_{jk} is 1 because units of output are in terms of a feed equivalent expressed in corn. The feed grain demand restriction is measured in this same unit, with total units representing the 1954 level of feed grain disappearance adjusted for normal livestock production. Coefficients in (7.12), a national demand restriction for food wheat, are also 1, since no distinction is made between types and classes of wheat (a detail corrected in later analysis). For requirements restrictions in both (7.11) and (7.12) an equality is used to indicate that annual production must equal annual requirements. Requirements are at 1954 level adjusted to normal livestock production, exports, population and food uses.

Feed grains other than wheat are combined into a single activity, with acreage in each region proportionate to the acreages in the period 1950–53 in this model. This procedure takes into account the fact that crops such as corn and small grains are grown in fixed rotational proportions in regions such as the Cornbelt. Computations were made with another model, not presented, in which each grain crop was considered to be independent. However, since it does not consider current rotational requirements, it probably over-estimates the magnitude and nature of regional adjustments needed in grain production, but is probably more realistic in predicting a greater acreage to be withdrawn.

Model B. This model is the same as A, except that land rent is included in the c_{jk}, the per unit cost of producing the jth crop in the kth region. The modification of B was used because only grain crops are included as competitive alternatives in programming. Inclusion of land rent as a cost in B gives recognition to alternative crops. However, since grains are the major crops in the regions programmed, market rents are largely based on feed grains and wheat. For this reason the estimates arising under Models A and C are believed to be more appropriate than those of B. Neither Model A nor Model B takes into account the magnitude of demand in each region.

Model C. This model is the same as A in nature and number of activities and restrictions and production costs. However, it gives recognition to transportation costs to regions of demand and also gives partial recognition to demand requirements in different regions. (If transport costs between regions of production and regions of demand, as well as demand magnitudes in each region, were readily available, the pattern of production which minimizes costs, including transport costs, to meet the "fixed" demand of each region, could be determined.) Instead of minimizing costs as in (7.9) we now maximize profit; X_k is as before but C_k is now a vector of net prices for the kth region. We assume that net prices in each region account for transportation costs to consuming regions. Using historic price differentials between these regions to reflect transport costs as they would be expressed in a purely competitive market, we use an equation similar to (7.9) to indicate the pattern of feed grain and wheat production which maximizes profit. This is equivalent to a minimum-cost solution under the above assumptions and assuming that the geographic markets absorb programmed quantities at implied prices. In an interregional competition manner, however, it is assumed that crops not included in X_k are lower alternatives than those which are included.

At 1954 levels of technology and consumption, a point in time where the large surpluses of the 1950's were only beginning to mount up, the models specified up to 35 million acres which could be withdrawn from production of wheat and feed grains (soybeans and cotton excluded), with annual output equated to annual disappearance of the crops mentioned. With progress of time, and technology increasing at a faster rate than population, the surplus acreage grew even more. However, the figures cited above refer to actual cropped land in the grains mentioned, and do not include derelict land of the character of much which went into the 1956 soil bank. Neither does it include land surplus to cotton production. But our interest here is more in the spatial reorganization of the nation's agriculture as it might be allowed to shift pattern with the developmental variables unleashed with time.

Regional Patterns of Withdrawal and Production

There is an important similarity in the regional production patterns resulting from the first three models. Figures 7.4, 7.5 and 7.6 indicate the regions in which production of feed grains and wheat would be located if average annual production were to equal requirements under the conditions assumed and if the geographic pattern of production were consistent with certain restricted comparative advantages of various regions. Figure 7.7 indicates the extent of agreement in number of times a particular region is specified for a particular use by the three models. The nonshaded areas include feed grain and wheat production at the same levels as in the base year. We assume that the small portion of grains produced in these nonshaded areas (8 percent of the total United States tonnage)

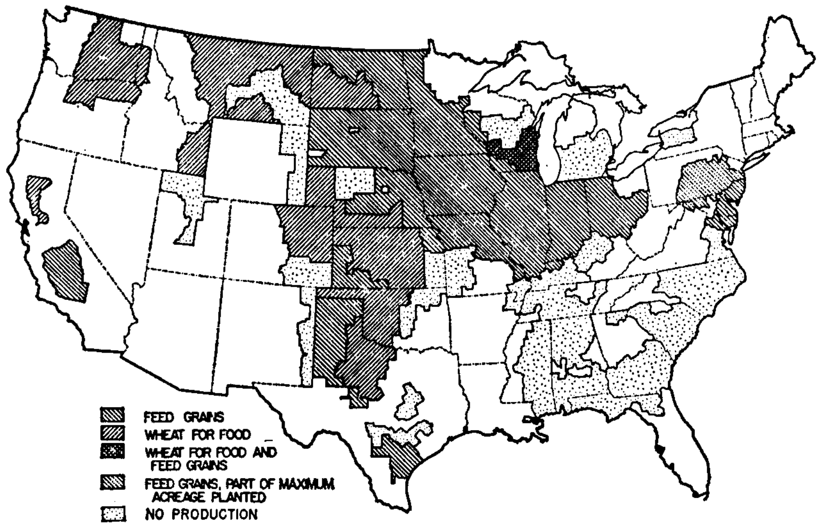

Fig. 7.4. Production Pattern Specified by Model A.

is grown for complementary and supplementary reasons and would largely continue even under competitive markets and prices. These regions were not included in the programming model.

Under the assumptions of Model A, regions would be withdrawn from production of all grains in southeastern Colorado, eastern New Mexico, northern Utah and eastern Wyoming and Montana. Regions scattered among Texas, Nebraska, Wisconsin, Michigan, Oklahoma, Missouri, Kansas and New York also would be withdrawn. In the Southeast, regions representing a large acreage would be withdrawn from production of grains. The *major* wheat and feed grain areas would remain entirely in production under the construction and assumptions of the models. Southwestern Kansas and western Texas would shift to sorghums for feed. Model B (Figure 7.5) provides a spatial production pattern differing somewhat from both A and C. The main differences under B are: All of Montana would be devoted to wheat for food, the Oklahoma panhandle and Pennsylvania would be shifted out of grains, and the region in southwest Missouri would be used for food wheat. Also, a large portion of Kansas would be used for both wheat and feed grain.

Under Model C, as compared to Model A, large parts of Montana, Washington, Oregon, Idaho and Nebraska would be devoted to wheat for feed only. In parts of Nebraska and Colorado wheat would be grown for both feed and food. In the upper Plains, North Dakota and South Dakota, along with parts of Minnesota and Wisconsin, would be devoted to wheat for food. Also, slightly more feed grain would be produced along the Atlantic Seaboard and the Gulf of Mexico. Under this profit-maximizing model, it is the relatively high wheat prices, because of location near larger milling and consuming centers and because of prices paid for hard red spring and durum wheats, which cause wheat for food to be specified in Minnesota and Wisconsin, as well as the Dakotas.

While there is considerable difference in the food wheat and feed grain patterns specified by Models A and C, they largely agree regarding regions specified to remain in grain production. Only five regions specified for production of some grain by Model C are not specified by Model A. Conversely, only one region specified to remain in grain production by Model A is not specified by Model C. Hence, only four more of the 104 regions would be needed to meet feed grain and food wheat requirements in Model C than in A. The five additional regions for fulfilling feed or food requirements under C include regions in eastern Virginia, northeast Ohio, western Kansas, southern Alabama and northern Utah. The region specified by Model A, but not by C, is in northeast South Dakota. Thirty-five entire regions and part of a small region in western Kentucky would not be required for grain production in Model C. These 36 regions represent the acreage which could be shifted to nongrain uses. The pattern is the same, except for the six regions noted above, for Model A.

Consistency or lack of consistency in the three models, as indicated by Figure 7.7, shows the major corn and winter and spring wheat areas to be specified to remain in production of grain in all three models. In a similar manner, all three models specify withdrawal from grain production of eastern Colorado and New Mexico, parts of Kansas, Oklahoma, Texas, Michigan and New York and practically all of the Southeast—from Arkansas, Tennessee and southeastern Virginia to the coasts. Only one model (B) specified grain production in eastern Wyoming, southeast

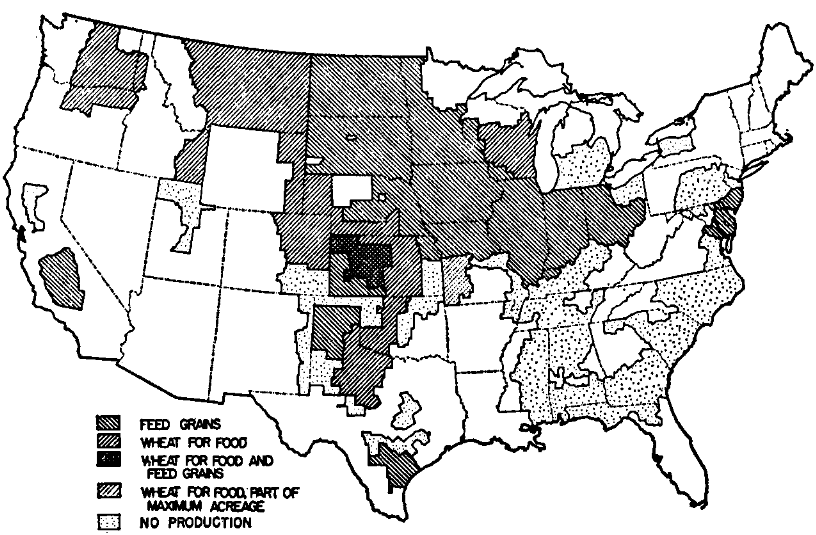

Fig. 7.5. Production Pattern Specified by Model B.

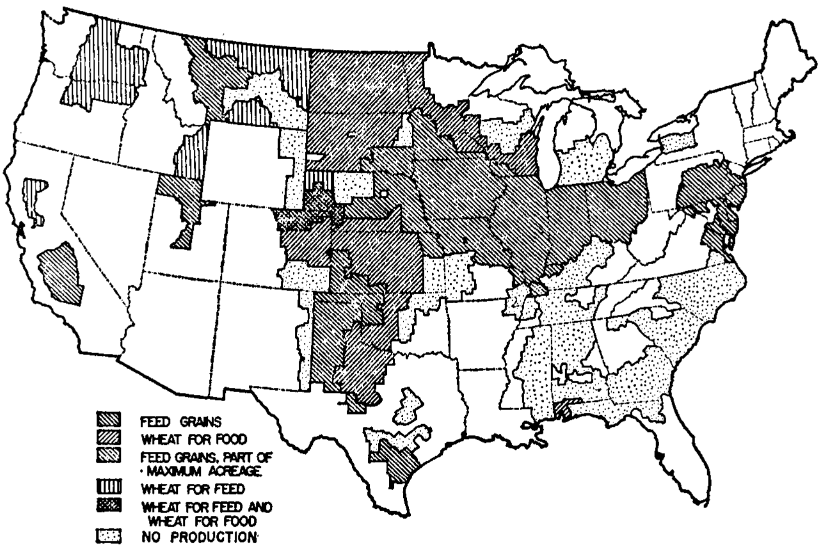

Fig. 7.6. Production Pattern Specified by Model C.

Montana, western Missouri and a few other scattered areas.

All three models are consistent for 88 of the 104 regions in the sense that they specify 88 regions (those indicated in Figure 7.7 as "all agree") that should remain in grain production or shift completely out of grains. Hence, disagreement among the three models existed for 16 regions. However, disagreement between Models A and C, the two models deemed most appropriate by the research workers, existed for only six regions in specification of feed grains apart from soybeans.

The fourth set of computations, based on Model D paralleling Model C but including soybeans and cotton, and computed for "1965 point in time," provides spatial results indicated in Figure 7.8. It assumes technology in fertilizer use projected to "profitable" levels at the present. Again the pattern largely is one of withdrawal of acreage over the low moisture areas of the Great Plains and the lower-yielding grain areas of the Southeast. Some regions of the Southeast would have increased comparative advantage in feed grain. The main wheat and corn areas remain devoted to these crops but some shift take place in cotton.[13] The market would not make "discrete distinction" between wheat for feed and that for food, since the two prices would be interrelated. Distinction on the map is made mainly to indicate those regions which would have relative advantage in producing wheat for feed, against other alternatives, even if food wheat had no advantage in price.

[13] The region in central Texas would be partly required for cotton production; the upper region of Minnesota and Wisconsin would be partly required for wheat and feed.

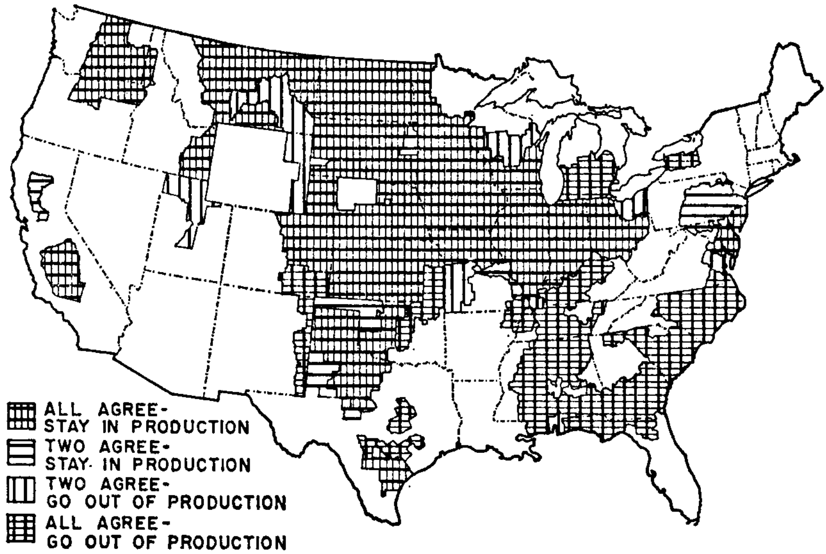

Fig. 7.7. Consistency of Three Models.

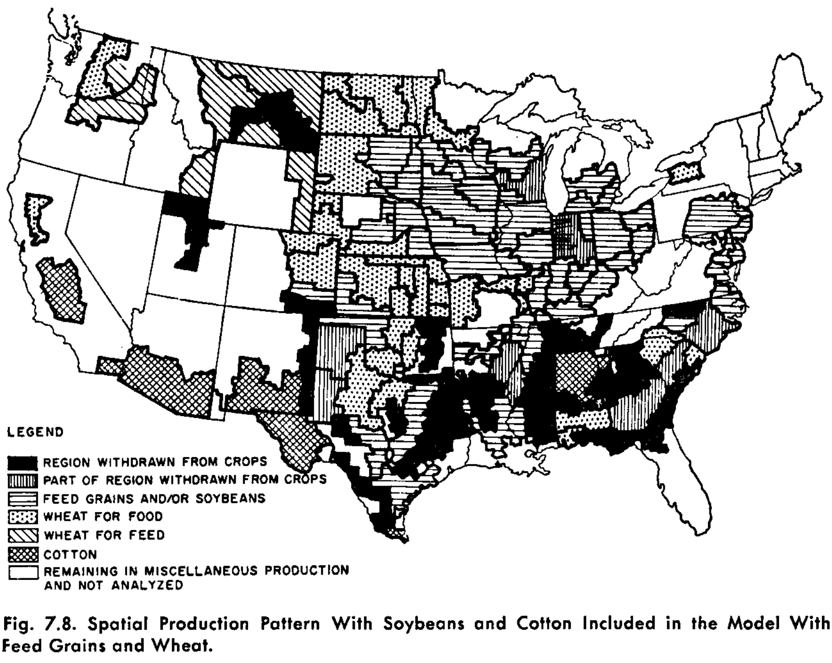

Fig. 7.8. Spatial Production Pattern With Soybeans and Cotton Included in the Model With Feed Grains and Wheat.

The models above have the limitations suggested previously, and in their "discrete" and linear nature. They are "over-all" in their indications, since parts of some regions indicated as "staying in" would actually shift out of the specified crops. Conversely, some parts of "going out" regions would actually remain in production, depending on their relative advantage. But the "over-all" effect would be to "shrink in" agriculture to the heart of the producing regions with greatest comparative advantage in the particular crops. The land shifted out would move into grass and trees, and even recreation, should the public decide to so invest.[14]

Surplus Acreage and Equity Distributions

The major surplus problems of agriculture have persisted because of the tenacity with which land inputs have clung to their conventional spatial and crop mixes. Had land been as flexible and adaptable as labor during the two decades following World War II, farm prices and income depression and treasury burdens would have been extremely lessened. The brunt of the farm "surplus commodity" problem rests, then, on the low elasticity of land supply to annual crops; and less so than on labor, although the two are inseparably interrelated at those margins of agriculture where shift needs to be from more intensive to less intensive crops.

Regional adjustment of production in directions of changing equilibrium, to bring annual output into line with demand would not be equally painless, or painful, to all producers. It would bring profit benefit to some and cost to others. If price-support programs were continued, with some surplus production, and a portion of annual output likewise continued to become immobilized from the market through government storage, farmers in regions where production was retained would not gain at any particular cost to producers of other regions who withdraw production. However, regional adjustment programs to withdraw grain production in those regions with lowest comparative advantage would have a long-run goal of bringing output in line with demand and of leaning more heavily on the pricing mechanism to guide resource use.

This use of prices need not mean complete elimination of storage and price support as a means of lessening instability. However, farmers who produce in regions of comparative disadvantage might rightfully claim, on the basis of welfare economics and distributive justice, compensation for their costs and contribution towards shifting agriculture to better conform with consumer demands. They would make sacrifices in both income and capital losses to bring (1) clearance of the market and (2) the opportunity for farmers of regions remaining in production to produce as much as would be consistent with their resources, production possi-

[14] The fact that some regions are indicated as shifting out of all crops included in the models need not preclude future technological innovations which might restore production. Because of computational burden, and not because of linearity restraints, the question of intensity of production was not examined. Also, while the techniques considered were those of 1954, and the magnitude of surplus capacity had grown by 1960, analysis assuming technology of later periods indicated the spatial pattern of farm re-alignment generally to coincide with the shifts indicated.

bilities and prices. Yet regions of high comparative advantage remaining in production could "produce to their heart's content." And many farmers with highest comparative advantage, being free to use new techniques and to feed more livestock, could earn even more at slightly lower grain prices. The burden of bringing production into equilibrium through this means would fall on those farmers who must drop out of annual crops and resort to the next closest alternative. This is a long drop in some wheat and cotton areas. Farmers in these concentrated areas could ask why they should stand the social costs involved in solving a surplus problem with earlier origin and perpetuated by programs designed to supplement incomes of farmers in areas of comparative advantage, as well as those in areas of disadvantage. This problem of gains to some against costs to others could be solved by various compensation schemes. (See Chapter 11 also.)

Means Available

Several means are available specifically to aid land-use shifts on a regional basis. One is direct purchase of land by the government. This approach may not be entirely consistent with U.S. value systems in times of general prosperity. There is need, however, for purchase of some land as national economic development and income growth continue.

One land product with a high income elasticity of demand and for which the nation is short is recreation. Other "higher-use alternatives" under economic growth, as outlined in Chapter 14, are forest products and grazing. Purchase of land might best serve in re-allocation from annual crops to forestry. But other systems of compensation need to be explored, especially for shifting to such uses as grazing. Systems of compensation other than direct land purchase may have greater public acceptance for major land-use adjustments. One method is Federal Government rental of land withdrawn from surplus crops, with investment in the seeding and other costs for shifting to grass and other specified uses. An alternative with simpler administrative and managerial requirements is purchase of farmers' rights to produce any crops but those specified over a relevant time period. Farmers could still handle the land, and most of the administrative and managerial problems in getting the shifts accomplished would fall into their hands. But for many farmers a sizeable increment in capital investment would be required for seeding and/or stocking land. Hence, a special credit program should be included in the "action bundle" to provide farmers with the assets for making the shift.

Abrupt adjustment of the regional pattern of production to the forces of economic development without any mode of compensation would have this supposition: The distribution of gains and losses from change are of positive-sum nature, with individuals who gain having greater change in utility than those who lose. Propositions in economics suggest that this knowledge is not given *a priori*. In this case, compensation is required as a guarantee of net community betterment. These propositions are examined further in Chapter 8.

INTENSITY OF AGRICULTURE

Shift of annual crops back to the heartland of the producing regions where advantage is greatest and away from the margins in terms of moisture and soil productivity would represent a decrease in intensity in use of resource. Less capital and labor would be used for land shifted from annual crops to grazing and forestry. But what about land remaining in conventional crops, and becoming relatively more specialized in them? With production as a continuous function of known inputs and known productivities as in (7.13), following equation (4.18), farmers could maximize profits in the sense of equating the derivative of product with respect to the ith resource against factor/product price ratios, as reflected in equation (7.14).

$$Y = f(X_1, X_2, \cdots X_i, \cdots X_g) \tag{7.13}$$

$$\frac{\partial Y}{\partial X_i} = \frac{P_i}{P} \tag{7.14}$$

A decline in product price, P with factor price, P_i, remaining constant would call for a larger partial derivative or marginal product. This could be attained only by decreasing the magnitude of X_i. Hence, if all farmers maximized profits in the static sense of perfect knowledge, an increase in the factor/product price ratio, brought about by freeing commodity price to be more effective in resource allocation, would lessen the magnitude of all inputs, the rate and degree of lag depending on the fixity of the resource and the rate at which its resources are given off over time.

The extent to which a given reduction in commodity price will reduce input and output, even under perfect knowledge, would depend on the elasticity of the production function. Under conditions of profit maximization, the elasticity for each factor, and as a sum for all factors, must be less than 1.0. Hence, a given percentage reduction in input will be accompanied by a smaller percentage decline in output.

Responsiveness in input and output will be by different proportions as can be illustrated by the simple production function represented in (7.15), with its accompanying marginal product and elasticity equations in (7.16) and (7.17) respectively. With a price ratio of 1.0, per unit price

$$Y = 5X - .2X^2 \tag{7.15}$$

$$\frac{dY}{dX} = 5 - .4X \tag{7.16}$$

$$E = (5X - .4X^2)Y^{-1} \tag{7.17}$$

of factor and product being equal, profit is maximized in the static manner of (7.14), with X equal to 10 and the corresponding output being 30. The elasticity for this combination is .333, indicating that reduction of input will be accompanied by a smaller percentage decline in output. In this case, a 1 percent decrease in input will decrease output by only .33

percent. If the factor/product price ratio now increases to 1.4, with price of resource constant and commodity price declining, the optimum input is now 9 and corresponding output is 28.8. Input has declined by $100(1 \div 10) = 10$ percent while output has declined by only $100(1.2 \div 30) = 4$ percent. The price ratio has increased by $100(.4 \div 1) = 40$ percent.

The facts are, then that the factor/product price ratio must increase by a greater percentage than input declines—which, in turn, is greater than the percentage decline in output. Or, in other terms: a decline of the price ratio by (say) 10 percent will be accompanied by a smaller percentage decrease in input and an even smaller percentage decline in output. (The elasticity of supply in respect to commodity price will be less than the elasticity of factor demand in respect to commodity price.)

Increase in factor/product price ratios, through absolute decline in commodity price are always expected to have their most immediate effect in checking input of resources such as fertilizer with short transformation periods, and greater lagged effect in checking input of longer-lived resources. (See Chapter 4.) Also, we know that uncertainty, capital limitations and other restraints on decision making prevent farmers from maximizing profits in the static sense of (7.14). But in these cases we expect the percentage decline in price ratio to exceed the percentage decline in input and output by an even greater proportion than where (7.14) does prevail.

However, it is worthwhile to review the production elasticity of such resources as fertilizer, to ascertain how a restructuring of prices for agriculture might be expected to reduce the intensity of production in specialized and other regions. To do so, we examine static supply elasticities derived from statistically derived production functions. The production functions, based on experimental data, have been used over the steps illustrated in previous chapters, namely, in computing marginal cost and then static supply and elasticity functions.[15] (The data also have been used to compute static factor demand functions and their elasticities. As pointed out above, the elasticity of static supply is generally less than elasticity of static demand.)

Figure 7.9 includes static corn supply elasticity curves derived for selected locations of the country. (Letters on curves indicate locations.)[16] The capital letters indicate the nutrient or nutrients (nitrogen, phosphate or potash) which are considered to be variable. At a price of \$1 for corn (with per pound prices of N, P_2O_5 and K_2O of 13, 8 and 5 cents respectively), static price elasticity is less than .3 for all functions and locations, meaning that a 10 percent decline in corn price would cause output per acre to recede by 3 percent or less, depending on the year and location,

[15] See Earl O. Heady and Luther G. Tweeten, *Corn Supply and Fertilizer Demand Functions Derived from Experimental Data; A Static Analysis*, Iowa Agr. Exp. Sta. Bul., forthcoming.

[16] The locations and soils are: (a) Clarion silt loam in Iowa with three nutrients variable, (b) same with *N* and *K* variable, (c) same with *P* and *K* variable, (d) Ida silt loam in Iowa, (e) Carrington silt loam in Iowa, (f) North Carolina coastal plain, (g) Kansas Verdigis soil, (h) Tennessee Lintonia soil, and (i) North Carolina Norfolk soils. Elasticities are computed on per acre basis of production functions.

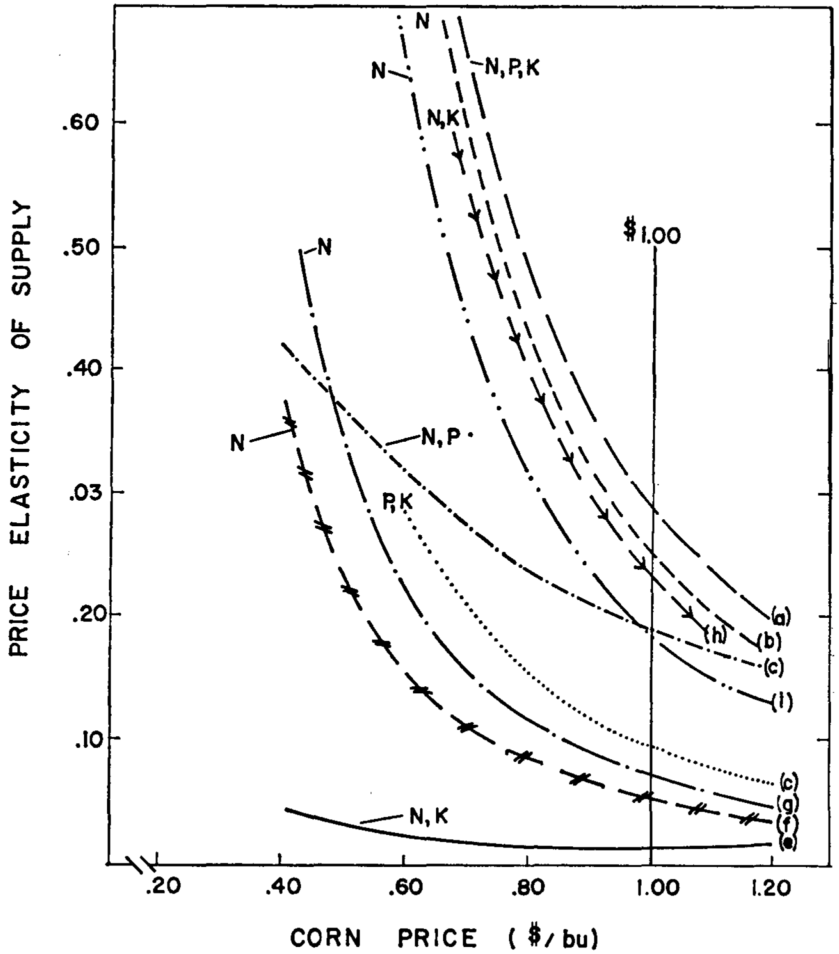

Fig. 7.9. Corn Supply Elasticities Derived From Static Supply Functions and Experimental Production Functions.

were farmers able to maximize profit and respond accordingly. Some of the functions indicate, at $1 price for corn, a decline of less than 1 percent for a 10 percent decline in corn price. At higher corn prices, the elasticity is even lower, just as it is higher for lower fertilizer prices. Elasticity of product supply so computed, as also is true of elasticity of factor demands, is low in regions of small rainfall because the corresponding elasticity of production is low.

While the illustration is for fertilizer and corn, the same general pattern is expected for other crops—along with annual inputs such as seed, irrigation water, insecticides and similar resources—if farmers used inputs to levels which maximized profits under price relationships of the

1950's. Typically, individual farmers do not drive the marginal productivity of all such factors to the level of the price ratio because of lack of knowledge, capital shortage, uncertainty and related phenomena. However, since the marginal product is then greater than price ratio, the latter can increase through commodity price decline without causing the magnitude of input to become uneconomic (except as it lowers the marginal value productivity of the resource and calls for a different allocation of scarce capital).

Both phenomena, low elasticity of commodity supply and factor demand based on low ultra-short-run production eleasticity and on inputs which do not drive marginal products to levels of price ratios in an individual farm context, probably mean that a re-gearing of U.S. agriculture to market and consumer preference would have but little effect on lowering intensity of production in the regions which remain specialized in particular crops. (Tobacco, and similar crops, might be an exception since fertilization rates are high, but elasticity of production is low accordingly.) Hence, it is proposed that the main readjustment to a different price schedule, output decreasing to demand levels, would be more the receding of production into the heartland of regions with comparative advantage in particular crops, with marginal areas shifting to other crops in the long run, and much less a reduction in intensity of biological capital resources in the specialized areas. Increase in farm size and reduction of labor force over these specialized areas is itself a reduction in intensity (especially of labor and mechanical capital), and magnitude of aggregate resource input, but not necessarily one to decrease output in the short run as noted earlier.

For particular crops, such as summer-fallow wheat, inputs are used in near-limitational manner. Where fertilizer is not used, seed bed preparation, planting and harvesting use a highly "fixed" collection of biological inputs per acre, with elasticity of production low or near zero. Regions remaining in production likely would use about the same quantity per acre of these physical and biological inputs, the major reduction in output coming largely from acres shifted to other crops.

It has been indicated that farmers do respond, even in the short run, to prices in use of particular resources. For example, equation (5.58) illustrates, year-to-year change in use of fertilizer in response to crop prices. However, this contraction does not come about only directly and causitively through a reduction of the right member of (7.14) but through that of the left member (in inability to buy inputs), due more nearly or equally to the effect on income and investment funds, degree of uncertainty and similar considerations. In post-war years, as the fertilizer/crop price ratio gradually declined, fertilizer use continued to go up, except in years of sharp break in farm prices. The increase came about as more farmers learned about fertilizer, as capital was accumulated, allowing them to drive marginal product of fertilizer to lower levels, and as capital-short farmers left the industry and their units were taken over by operators longer on capital supply. This trend can continue for some time before the condition of (7.14) holds true generally for fertilizer in U.S. agriculture.

RELATIVE IMPORTANCE OF FACTORS

The following conditions have caused the relative mix of inputs in agriculture to change: Constancy of land supply and the continuous development of substitutes for it, changes in the relative prices of labor and capital and technical development of capital items with increased marginal rates of substitution. This trend, with output embodying many fewer labor services and much more capital, will continue with national economic development.

As Table 7.7 indicates, labor input requirements represented nearly 75 percent of all inputs in 1910, but had fallen to less than a third of inputs by 1960. In contrast, inputs of capital had risen from less than a quarter to nearly two-thirds of all inputs. (If we include land as a "financial" or capital input, total capital increased from 25 percent in 1910 to 70 percent in 1959.) Land, as a proportion of all inputs, apparently has remained about constant, but perhaps has decreased since 1940. Constancy in relative importance of land is itself significant. In the absence of technical development and with declining long-run elasticity of production and supply functions for food, food price would have risen. Land, a factor of lowest supply elasticity, would thus have grown in relative value importance and contribution. As it is, capital substitutes have caused a near-fixed supply of land to remain relatively constant in its input value contribution to agriculture's output. The figures in Table 7.7 include land producing surplus crops in the period 1930–60. Estimates state that surplus cropland was as much as 10 percent of the total for the 1950's. With this amount of land services subtracted out, the data of Table 7.7 would show a decline for land. (We present data in Chapter 14 suggesting more clearly a decline in "value productivity importance of land."[17]) But at the maximum, land has not grown in relative contribution to farm output, as would be true under growth of population and food demand and constancy of agricultural technology.

The data of Table 7.7 also are significant in their reflection of the growing relative importance of capital. In 1910, with major inputs being those of labor, the beginning or other farmer could make his living largely with the resources representing his human endowment. Pressure of economic development through factor markets touched him but little, because his own person represented the major input. In 1960, however, this situation was reversed, with capital representing over 70 percent of total inputs if land is included. Hence, in later periods, capital and its investment in large scale becomes a necessary condition for success and income. Too, farm income is much more the direct functon of the factor

[17] For earlier propositions to this effect, and explaining the nature of land-substituting and land-using innovations, see Earl O. Heady, "Changes in Income Distribution in Agriculture With Special Reference to Technological Change," *Jour. Farm Econ.*, Vol. 24.

TABLE 7.7

PERCENT OF TOTAL ANNUAL INPUTS OF AGRICULTURE REPRESENTED BY LABOR, LAND AND CAPITAL (1910–60, SELECTED YEARS)[a]

Year	Labor	Land	Capital	All Inputs	All Inputs as Percent of 1910[a]
1910........	74.6	8.7	16.7	100.0	100.0
1915........	72.6	8.4	19.0	100.0	105.9
1920........	70.1	8.3	21.6	100.0	113.1
1925........	69.3	8.0	22.7	100.0	113.6
1930........	65.8	8.3	25.9	100.0	115.2
1935........	66.7	9.6	23.8	100.0	104.4
1940........	58.6	9.1	32.3	100.0	115.6
1945........	52.5	8.9	38.7	100.0	118.7
1950........	41.8	8.9	49.3	100.0	119.8
1955........	35.0	8.6	56.5	100.0	120.5
1959........	30.1	8.5	61.4	100.0	121.3

Source: Basic Data from Agricultural Research Service, USDA. See page 232 of *Economic Report of the President, 1960* and USDA Tech. Bul. 1238 for the basic series. Proportions are values of annual inputs with deflation to a 1947–49 dollar basis. Capital includes interest on investment plus depreciation (cost for annual inputs). Land includes rental and interest value of annual input. Labor is physical requirement times wage rate.

[a] Based on all inputs but taxes excluded. Without taxes included as an input, the index differs slightly from that used in earlier chapters.

market, since capital and investment comes almost entirely from the market and not directly from the household.

Output in Relation to Input

Examination of Table 7.7 again emphasizes an important characteristic of U.S. agriculture under economic growth, namely, the tendency for output to increase with a highly "constant" aggregate input, with a consequent large growth in the output-input ratio. The input aggregation is made for the data of the table by computing annual inputs on the basis of depreciation of durable capital, price of mono-period resources, interest on durable capital and land, and wage rate for labor, all converted to a constant value of the dollar. If all inputs have been accurately measured in this aggregation, with the prices for input of resources of nonfarm origin incorporating services used in these resource-furnishing industries, society is indeed fortunate in having a larger food output produced, in fact, with less aggregate resource per unit of aggregate product. Important weighting problems are involved, but even with some error due to this, it appears certain that the output/input ratio has declined remarkably and aggregate input has remained highly stable, with labor decline offset by capital increase, or increased remarkably little with a much greater output.

We now inquire how these changes might be possible, supposing that important inputs have not been neglected in the data of Table 7.7. The production process is not adequately represented by a production function in which there are only three factors of production, capital, labor and land. It is better represented by a production function such as (4.18), where n may be equal to several thousand, with many possible categories of specific inputs. Some of these resources are known. If their price is not too high relative to productivity, they are used in positive quantities. Some are unknown, and their input is zero. Input of others, zero for centuries because they or their productivity coefficients were not known, increased rapidly as innovation identified them. The role of technical innovation is to identify these hundreds of individual resources and their productivity coefficients so that they can be used in nonzero quantities if prices are favorable. Granulated ammonium nitrate 2-4D, Pioneer 907 hybrid seed corn, row crop tractors and irrigation water in Indiana are resources distinctly different from rock phosphate, pig weeds, open-pollinated or best 206 hybrid seed corn, mules and winter snow in Indiana. The production process is not adequately represented if we aggregate these many different resources into a single resource category, capital or value of inputs, and try to explain changes in the physical production function. These distinctly different resources, some known and some yet unknown, serve as substitutes for each other. Input of some has increased by extremely large magnitudes over the past several decades, with a consequent decrease or disappearance in others.

Innovations generally would not be adopted if they failed to lessen the value of inputs (the measure conventionally used for aggregate input) required to produce a given output. This is an obvious reason why continuous innovation would lead to a decline in capital value of inputs relative to output. For an individual farmer, and in aggregate for the agricultural industry, the situation is like that represented in Figure 7.10.

We could examine the case in which both an individual form of resource (technique or capital form) and its productivity coefficient are unknown or the material or resource (hybrid corn) is known but its productivity coefficient is not. For simplicity purposes, we use the second example, although the logic is the same in both. Suppose that one particular resource (such as open-pollinated corn or horsepower) in the *total* production function is known and is X_g. Another particular resource (hybrid corn or tractors) newly discovered or identified is X_h. However,

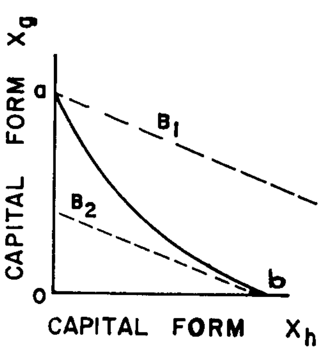

Fig. 7.10. Effect of Innovation on Value of Input Per Unit of Output.

nothing is known about its productivity coefficient. Therefore, the product isoquant in Figure 7.9, denoting substitution rates between the two distinct resources or materials, is unknown. Hence, the amount of X_g used to produce the given quantity should be a, if profits are maximized in the situation. Although both materials may have a price, with the price ratio represented by the slope of B_1, only resource X_g is used because the effects of resource X_h are unknown. Now suppose that research uncovers the productivity coefficient and establishes the isoquant ab. Given the price ratio indicated, costs can be lowered (the amount of capital or value quantity of all inputs can be decreased) and profits increased by substituting resource X_h (hybrid corn or ammonium nitrate) for X_g (open-pollinated corn or ammonium sulfate), to the extent of b. In doing so, capital resources measured in dollar value decline from the level B_1 to B_q. Farmers figure this out for themselves and lower "capital value inputs" for any given output. They would be foolish indeed to substitute one physical resource for another which increased "value inputs" for any given output. For this reason, the one physical resource is substituted for another in producing a given output, and the basis is laid for producing more output without a similar increase in "dollar-aggregated" input.

But in addition to a substitution effect, a price effect, in respect to quantity of output and resources used after the innovation, is expected. In this case, output can expand with a smaller "dollar capital input" as long as the equilibrium production is less than that denoted by an isoquant tangent to B_1. Given the particular geometry, output could be more than doubled, while inputs valued on a dollar basis would show a decline.

That which would hold true for an individual farm could also hold true for the agricultural industry. Or, if a curved iso-revenue line is assumed, the figure would apply equally to the industry. Of course, if price elasticity of demand for the product were sufficiently great, the price effect of the innovation (discovery of the new resource form) could cause a sufficient increase in output to also cause dollar value (capital as conventionally measured) of inputs to increase, but the latter would not increase by the same proportion. If demand were sufficiently inelastic, the increase in output would be produced with a proportionately smaller increase in input. Agriculture is notably "low" in respect to demand elasticity coefficients.

To better illustrate conditions under which output might increase at a greater rate than input, given the situation of demand elasticity and technical advance of agriculture, a very simple algebraic example is now used. It illustrates that the phenomenon might be explained by conventional concepts in economics without need to resort to a yet undeveloped growth theory. A simple model with some numerical coefficients is used for simplicity and ease of following by the reader, but other algebraic forms and coefficients would give similar results under the elasticity and technical conditions which characterize agriculture.

First, we suppose a demand function of a form indicated earlier and repeated in (7.18), with quantity expressed as a function of price and a price elasticity of $-.4$ exceeding that at farm level for food products in aggregate. (We might consider the demand and production functions to relate to a particular product or to products in aggregate. The results, in respect to magnitude of output relative to input, are the same in either case for elasticities and changes such as those used for illustration.) For illustrative and simplicity purposes, the variables in the demand function are those enumerated earlier, namely Q_d, the amount purchased at any particular price, P, and c, a constant to reflect the effects of income, population magnitudes and related variables at a particular point in time.

$$Q_d = cP^{-.4} \tag{7.18}$$

$$Q_p = \pi X_g^{.8} \tag{7.19}$$

The production function used for illustrative purposes follows that of equation (2.3) and is that of (7.19), where X_g is factor input and π is, as outlined earlier, a coefficient to reflect the effects of a quantity of fixed resources and technical conditions at one point in time. The g subscript indicates that resource input is in a form representing an early stage of innovation (open-pollinated corn, horses, oats without ceresan treatment, etc.). Obviously, as the state of the arts increases (π becomes larger), a smaller quantity of resources, X_g, will be required to produce a given amount of product. The variable X_g refers to resources used in the form of particular techniques at one point in time. It could be a quantity measured by some standard such as mass (tons) or value (constant dollars). The elasticity of .8 is arbitrary, taken to illustrate a fixed plant in acreage for a given state of arts.[18] Hence, at a given point in time, an increase in quantity of inputs representing given techniques would result in an increase in output by a smaller proportion.

Expressing input requirements as a function of output, computing total cost, equating its derivative to commodity price and solving for Q, we obtain the supply function in (7.20). Equating (7.20) to demand in (7.18) and solving for P, we obtain the equilibrium price in (7.21) where P_x is price of the resource:

$$Q_s = .4096\pi^5 P^4 P_x^{-4} \tag{7.20}$$

$$P = 1.22496c^{.2273}\pi^{-1.1365}P_x^{.9092} \tag{7.21}$$

Substituting the equilibrium price into demand and supply functions, the equilibrium output is (7.22). From the production function (7.19), the equilibrium resource input is thus (7.23).

[18] By using an elasticity of production smaller than 1.0, we do not assume diminishing returns over (to) time. As illustrated later, innovations can (as actually experienced in agriculture) allow output to increase by a greater proportion than inputs.

(7.22) $$Q = .9223c^{.9092}\pi^{.4540}P_x^{-.3632}$$

(7.23) $$X_g = .9037c^{1.1365}\pi^{-.6825}P_x^{-.4540}$$

The equilibrium output/input ratio is that in (7.24) which represents an index of 100 for this period.

(7.24) $$QX_g^{-1} = 1.0204c^{-.2273}\pi^{1.1365}P_x^{.0908}$$

(7.25) $$Q_p = \Gamma\pi X_h^{.8}$$

Now suppose demand growth takes place with increase in population in the manner that (7.18) is multiplied by λ (or $\lambda = 1.0$ in the original function but $\lambda > 1.0$ after the increase). Further, technical advance changes the production function by the ratio Γ, more product being obtained from a given tonnage, value (constant dollar) or other physical measure of input as in (7.25) where the subscript h now refers to the new form of resource in the same unit of measurement as X_g. The proportionate increase in equilibrium output, r_q, resulting from the increase in demand and technology, is that in (7.26). The proportionate increase in equilibrium input, r_x, is that in (7.27).

(7.26) $$r_q = \lambda^{.9092}\Gamma^{.4540}$$

(7.27) $$r_x = \lambda^{1.1365}\Gamma^{-.6825}$$

These two proportions (i.e. rates of increase in input and output) are the same only under the conditions of (7.28), indicating that the rate of increase in resource productivity, resulting from technical improvement, must be much smaller than the rate of demand increase if the rate by which equilibrium input increases is the same as the rate at which equilibrium output increases.

(7.28) $$\Gamma = \lambda^{.2}$$

(7.29) $$Q = 1.6728c^{.9092}\pi^{.4540}P_x^{-.3632}$$

Thus, if the proportionate increase in demand were 1.5 (i.e., the demand function in (7.18) were increased by 1.5) as a result of increases in population and income, the production function could increase only by the much smaller fraction or by 1.08; the production function in (7.19) could be multiplied by only 1.08 if ratios of increase were to remain the same.

As a further example, suppose the λ is 1.5 while Γ in (7.25) is 1.65, indicating that demand and resource productivity have increased by these proportions. The output and input quantities will now be those in (7.29) and (7.30) respectively, as compared to those in (7.22) and (7.23) before the improvement in demand and technology.

(7.30) $$X_h = 1.0170c^{1.1365}\pi^{-.6825}P_x^{-.4540}$$

In other words, equilibrium output is 1.82 times (82 percent) greater than before the improvement and technology, while equilibrium input is only 1.13 times (13 percent) greater. Obviously, the relative demand and physical resource productivity depends on the elasticity coefficients. The output/input ratio has increased from that in (7.24) to that in (7.31), or by 37 percent. (The index now stands at 137 as compared to the base period.)

$$QX_h^{-1} = 1.6448c^{-.2273}\pi^{1.1365}P_x^{.0908} \tag{7.31}$$

The magnitudes of the elasticity coefficients and the demand and production multipliers concerned have caused inputs to increase by a smaller proportion than output. It is obvious that the relative rate at which inputs and outputs change, with given change in demand and techniques, will depend on the production and elasticity coefficients. Or, with given elasticity coefficients, the relative rate of increase between output and input will depend on the rate of growth in demand and technical advance. The change in ratio of output to input will be greater as the price elasticity of demand is lower or as the elasticity of production is greater. If the elasticity of production is sufficiently great relative to λ, input can even decline while output is increasing. Or, if the price elasticity of demand is sufficiently low, an improvement in techniques which results in a higher transformation rate of resources (measured in some standard unit such as dollars, tons, etc.) and a greater elasticity of production, output can increase while input (measured in the standard units) is decreasing.[19] For simplicity purposes in our example, demand and technical change are reflected through the two multipliers, with the elasticity coefficients remaining constant. Actually, the tendency is for price elasticity of demand to decline with growth in income and perhaps for the agricultural production elasticity to increase with technical innovation. Incorporation of these changing elasticity coefficients into the example would cause the growth in input to be restricted even more relative to growth in output.[20]

There are two general cases under which the output/input ratio would remain constant (i.e., the index of output divided by the index of input would remain at unity) over time. One is the case of constant resource productivity (an elasticity of coefficient of 1.0) and no improvement in

[19] For example, if we start with the original demand and production functions and increase the demand function by the ratio $\lambda=1.3$ and the production function by the ratio $\Gamma=2.0$, equilibrium output will increase by the ratio $r_q=1.7388$ or by 73.9 percent while equilibrium input will decrease to the ratio $r_x=.8333$ or by 16.7 percent. This is true, for the elasticity coefficients used, because $\Gamma>\lambda^{.2}$. In other words, equilibrium input can decline absolutely while output increases if the elasticity of production and Γ, the change in technology, are sufficiently great relative to the demand elasticity and λ, the demand multiplier.

[20] We determined equilibrium output and input in the classical example which did not allow for discounting due to uncertainty and other causes. However, even if a discount coefficient were attached to the supply functions before and after innovation, the result would be the same for equal discounts. Even with a growth in the discount coefficient, output could still increase more than input, if the rate of technical improvement and the elasticity of production are sufficiently large.

techniques as demand increases. The other parallels that above where production elasticity is not unity and the improvement in technology must bear some particular relationship to the increase in demand, given the elasticity coefficients. But in neither of these cases, with the ratio of output to input remaining constant, or the ratio of increases remaining at unity, would society in general gain, as compared to the case in which the output/input ratio increases with time.

For example, starting with the first case, if the original demand is that in equation (7.18), while the production function is $Q_p = \pi X_g$, an elasticity coefficient of unity, the equilibrium output/input ratio then is π. Now if demand increases by the proportion λ, while technical improvement does not take place, the equilibrium output will increase but the equilibrium output/input ratio will remain constant at the original value of π. Society would gain more if technical change also could occur at the rate of $\Gamma > 1.0$, so that the output/input ratio could increase to $\Gamma\pi$, rather than to remain constant. Then for a given agricultural output for consumers, an amount of resources equal to $\Gamma^{-1}X_g$ could be transferred to production of other goods and services. However, farmers in aggregate would not gain in revenue because of the low price elasticity.

As a second case, with the elasticity of production not at unity, suppose that demand and production functions are originally those in (7.18) and (7.19). Now suppose that through demand increases λ becomes 1.5 and, through technological improvement, Γ becomes 1.0845. Under this very small improvement in technology, equilibrium output will be that in (7.32) while the equilibrium input will be that in (7.33).

$$Q = 1.3825c^{.9092}\pi^{.4540}P_x^{-.3632} \tag{7.32}$$

$$X_h = 1.3548c^{1.1365}\pi^{-.6825}P_x^{-.4540} \tag{7.33}$$

The new equilibrium output/input ratio will thus remain constant at the level in (7.24) and the index ratio, output index over input index, will remain at unity. This condition, attained by holding technical improvement at a very low level, is not desirable from a consumer welfare standpoint. The same output could be attained by a saving of resources if we caused the output/input ratio to increase through a more rapid pace in technical improvement. In fact, the output in (7.32) could be attained by an amount of resources equal to (7.34) if we allowed Γ to be 1.65 rather than to restrict it to 1.0845.[21] In other words, we could save the proportion,

$$1 - \frac{.8017}{1.3548} \quad \text{or} \quad 44.9 \text{ percent},$$

of the resources used in producing (7.32), if we allowed the output/input

[21] Computed by setting $1.65\pi X_h^{.8} = 1.3825c^{.9092}\pi^{.4540}P_x^{-.3632}$ and solving for X_h where the left-hand quantity is from (7.25) with $\Gamma = 1.65$ while the right-hand quantity is Q in (7.32) the equilibrium output where we hold technical change to $\Gamma = 1.0845$.

ratio to increase to the level consistent with $\Gamma = 1.65$, rather than to hold it constant at the level of $\Gamma = 1.0845$.

$$X_h = .8017c^{1.1365}\pi^{-.6825}P_x^{-.4540} \tag{7.34}$$

Obviously, it is economically more desirable to consumer welfare to have the index ratio, index of output divided by index of input, increase with time (i.e., depart from unity) because it is then possible to get a given percentage increase in output, to meet increased demands, with a smaller percentage increase in inputs. This statement is in terms of overall economic development and long-run consumer welfare. But, again, and in the short run as a particular sector of society, the revenue to farm producers can decline because of low price elasticity of demand for food in aggregate. It is this problem of gain to consumer sector but sacrifice to producer sector which is the crux of policy where the general level of income per capita is high and all groups wish further gain in income, both as members of a wealthy society and of a group contributing to economic progress.

TECHNOLOGY AND STRUCTURE OF AGRICULTURE

We have already indicated that had all technical knowledge—the resources entering into agricultural production functions with positive productivities—been known from the outset, structural development of the industry would have followed a pattern quite similar to that of the last two centuries, perhaps the main difference being the speed and timing of change in resource mix and supply structure.

Large and elastic supplies of labor and land at low relative prices, with the opposite true for capital, early would have favored labor types of agriculture with low capital intensity, small units and a large farm population. But with resources shifting relative position in supply and price, emphasis is on large units, a smaller labor force and rural population and a more intensive use of capital or technology with given plant in land acres. We should expect this pattern of structural modification to continue under the continuous change in relative supply and price of resources under further economic development.

Since the endowment of resources by nature to agriculture was not equal over space, differential advantage will occur by regions as encouraged by changing resource prices and as allowed by technical knowledge. Agricultural policy per se can do little to stop these forces of national factor markets which reach over into agriculture and alter the resource and supply structure of the industry, unless it goes so far as to check national economic growth. But this is a Herculean and likely impossible accomplishment on the part of agricultural policy. The variables found in agriculture, per se, now have too little influence on the total economy, given the decline in proportion represented by agriculture.

Farm policy can only attempt to manipulate variables in agriculture which have an effect contrary to those variables reaching into the industry from outside factor markets. Even in the realm of technical change, farm policy can do much less than in the past. This is true because nonfarm or purchased inputs are coming to dominate agricultural production and supply. Under this condition, nonfarm sectors invest more heavily in uncovering and communicating the productivity of new resources to farmers. Even if the public were to cease investment in research and communication of technological change, the activity would continue at rapid tempo, financed by outside firms with even greater emphasis on resources and capital items produced external to agriculture. (Major resources such as machinery, tractors, hybrid corn, stilbestrol and others were discovered or developed outside of public research institutions.)

But how far can substitute resources go, in effectively replacing land and labor by capital? Relative prices are only one set of data determining factor combinations. Relative productivities and marginal rates of substitution are quantities of equal importance. Are we approaching the mathematical limit of zero-rate in substitution of capital for labor and land in agriculture? This proposition is not infrequently put forth, just as it was by Malthus and Ricardo. Thus far, diminishing marginal productivity of conventional capital items has always been offset by development of new capital items or technologies with greater marginal rates of productivity and substitution (a jump from curve representing one production function to one representing a new function, rather than movement along the first).

An important portion of the increment in yield per acre has come from fertilizer and improved varieties. Agronomists estimate that of the 17.5 bushel increase in corn yield per acre between 1940 and 1958, about 47 percent came from fertilizer and 40 percent from improved seed.[22] Fertilizer is an input which has spread rapidly over the U.S. since 1940. Its use increased several-fold in the two decades, 1940–60. (See Chapter 5.) It has served as a tremendous substitute for both land and labor. It is still used in relatively small quantities by many farmers who could, from an individual rather than aggregative basis, profitably employ it. Fertilizer still has considerable slack, in the sense of being spread to many farms at relatively low level of input. But after this has been accomplished, the next opportunity is in using it at higher level of input on farms already using it. While much more fertilizer can be used following the second route, it will have a much lower marginal rate of substitution for land. Table 7.8 illustrates the declining marginal rate of substitution of fertilizer for land when input is of particular magnitudes. These computations, following equations (2.22) to (2.26), would also indicate a decline in marginal rates of substitution of fertilizer for labor as the former is used more widely and intensively. The data are for particular soils (those indicated for Figure 7.9), climatic conditions

[22] L. M. Thompson *et al.*, *Causes of Recent High Yields in Feed Grains*, Iowa Center for Agricultural and Economic Adjustment, Iowa State University, Feed-Livestock Workshop, Ames, 1959, pp. 15–39.

TABLE 7.8

MARGINAL RATES OF SUBSTITUTION OF FERTILIZER NUTRIENTS (LBS.) FOR LAND (ACRE) IN CORN PRODUCTION BASED ON PRODUCTION FUNCTIONS AT PARTICULAR LOCATIONS*

Rate of Application (Lbs. Per Acre)	North Carolina (*f*)	Kansas (*g*)	Miss. (*j*)	Iowa (*a*)	Iowa (*e*)
25	.0247	.0035	.0089	.0394	.0027
50	.0181	.0025	.0018	.0014	.0021
75	.0121	.0014	—	—	.0016
100	.0074	.0004	—	—	.0013
125	.0034	—	—	—	.0010
150	.0018	—	—	—	.0007
175	.0002	—	—	—	.0005

* Refer to Figure 7.7 for sources and soil type. (*j*) indicates Mississippi experimental data for corn. The marginal rates of substitution are computed as in equation (2.23) where $Y = f(X)$ is the original experimental production function with Y yield per acre, X fertilizer per acre and A land acres. The original function is computed on a per acre basis, and is multiplied by A to indicate production from varying acreage at the various input levels. Hence, the substitution rate is of fertilizer for the particular soil. Rate would be greater if we compared fertilizer on central Iowa soil with the number of acres which could be thus replaced in the northern Ozarks. Too, the substitution rates are "gross physical rates," since they do not account for other inputs such as labor.

and other variables. Hence, they do not serve as a predictive base for U.S. agriculture as a universe. They do indicate, however, that as average rate of fertilization moves up a scale of 25, 50 and 75 pounds per acre, the rate of replacement of land by fertilizer capital declines. Given constancy of other techniques, the opportunity for substitution of fertilizer for land is not as great for the future as for the past.

However, the restraint of "constancy in other techniques" has not been operative in past decades, and mathematical limit of zero productivity for input extensions has been lifted by development of new techniques or capital forms which complement certain of the old. Previous data presented indicated that the supply function of food will have sufficient elasticity over the next decade, or perhaps two, that farm surplus problems are more probable than deficit and high real price of food. The extent to which food has high or real cost beyond that time depends on the success and magnitude of investment in research in biology related to agriculture, but it also may depend on chemistry as it is practical in synthesizing foods outside of agriculture.

For the next decade, however, capital can continue to substitute for land and labor. At 1960 point of time, various estimates predicted that from 40 to 80 million acres (10 to 20 percent with the amount depending on the method of withdrawal) of U.S. cropland could be withdrawn from production without material effect on retail price of food.[23] (See Chapter 14.) Christensen, Johnson and Baumann predict this surplus acreage will grow over the next half dozen years.[24] The supply of land, in relation

[23] See Heady and Egbert, *op. cit.;* Earl O. Heady and Arnold Paulson, *U.S. News and World Report,* May 30, 1960, pp. 104–6; and J. Carroll Bottum, *Increase the Conservation Reserve,* Iowa Center for Economic and Agricultural Adjustment, Feed-Livestock Workshop, pp. 141–49; R. P. Christensen, S. E. Johnson and R. V. Baumann, *Production Prospects for Wheat, Feed and Livestock,* 1960–65.

[24] *Ibid.,* pp. 43–115.

to food demand and productivity and not in physical extent, was greater in 1960 than at any time in the previous half century. The effect of capital substitution on supply was equivalent to discovery of a new land area the size of Iowa or Kansas. Nations concerned with stepping up rate of economic development and alleviating problems of population pressure would rejoice in this equivalent of discovery. It provides assurance and certainty for U.S. consumers, plus perhaps others of the world, and is an important product of economic development. Yet its net benefits will not be reflected fully to society until a later time when supply of land is made more elastic to grains and other products of agriculture for which surpluses are prone to develop, and until policy guarantees distribution of gains with positive-sum utility outcome over all major groups of producers and consumers.