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Toward a Policy Model of World Economic Development with Special Attention to the Agricultural Sector

KARL A. FOX
IOWA STATE UNIVERSITY

TWO MAJOR VIRTUES of J. A. C. Brown's model are comprehensiveness and consistency. It reminds us very clearly that the world economy is a closed system. The exports of one country are imports of other countries. Inconsistencies among the export plans of different countries can be clearly exposed and quantified only within a complete model which includes all countries (or, as in Brown's model, all multicountry regions).

Except for minor editing, Brown's paper appears in this volume just as it stood in August 1965. If the Food and Agriculture Organization has decided to use this framework for its studies underlying the Indicative World Food Plan, Brown and others would no doubt have enriched and improved the model. As this did not happen, I propose to add some suggestions of my own toward a model of world economic development with special attention to the agricultural sector.

World economic development requires the transformation of agricultural production. It also entails the transformation of both rural and urban social systems. During the development process, such dualism as may exist initially is resolved into monism of the kind reflected in the symmetrical treatment of agriculture and other sectors in an input-output matrix. The rural-urban dichotomy is also resolved into a system of functional economic areas which are essentially urban in character. Hence, I will take a broader approach here than is customary in discussions of agricultural development.

World economic development has implications for every human being. More than a billion persons are now living in villages and are engaged primarily in agriculture. Within two decades hundreds of millions of them will have changed occupations, residences, and ways of life. Increased efficiency of agricultural production is one element, but only one, in the development process. Noneconomic aspects of life may change so drastically that changes in real income per capita will be partial and inadequate measures of changes in human welfare. To guide agricultural development policies on a world scale we need a concept of individual welfare that goes beyond that represented by existing measures. It will require the application of a comprehensive social science and the integration of units of observation from psychology, sociology, and economics. We must also bring to bear the concepts of central-place theory to clarify the nature of the urbanization process and the emergence of a new synthesis of rural and urban society around national (or multinational) systems of cities.

Apart from these innovations, the role of agriculture in world economic development can be expressed by linking several types of quantitative models. These models have generally been applied by different groups of economists in different contexts, and there may be some advantage in spelling out the way in which they could be integrated to form a policy-oriented model of the world economy with a realistic, operational, and computable treatment of the agricultural sector.

I

Toward a Comprehensive Social Science

There are indications that leading social scientists in a number of fields are converging toward a comprehensive social science. In his 1957 collection of essays, *Models of Man,* Herbert Simon tried to set forth "a consistent body of theory of the rational and nonrational aspects of human behavior in a social setting." [1] The essays collected in that volume had appeared in thirteen journals, representing statistics and all the

[1] Simon, Herbert A., *Models of Man: Social and Rational,* New York, 1957, p. vii.

social sciences save anthropology. Simon commented wryly on the compartmentalization of readership of these journal articles:

> I am afraid that economists are aware of them chiefly as they impinge upon the theory of the firm, social psychologists and sociologists as they relate to small group theory, learning theorists as they relate to problem solving, political scientists as they relate to the phenomena of power, and statisticians as they relate to the identification problem. The new wine, such as it is, has been safely stored in the old bottles—and I am often complimented, sincerely I think, on the range of my dilettantism.
>
> In assembling these sixteen essays in a single volume, together with some analysis of their mutual relations, I make confession that the compliments were largely undeserved; that what appeared to be scatteration was really closer to monomania. For when these essays are viewed in juxtaposition, it can be seen that all of them are concerned with laying foundations for a science of man that will accommodate comfortably his dual nature as a social and as a rational animal. The unity of the essays lies in that goal and in the fact that, as the foundations began to take shape, they clearly rested on two principal mechanisms—the mechanism of influence and the mechanism of choice.[2]

In his presidential address before the Regional Science Association in November 1966, William Warntz said:

> There is an ever-growing danger that events will come to control men completely. If men of good will and high purpose are to control events, they must be trained to perceive and taught to act in accord with a lawful universe—social as well as physical—and their sympathies must be supplemented by the kind of knowledge that can come only from a well-integrated, pertinent social science.
>
> And, if this kind of social science is to emerge, it must be not only unified and related to all the disciplines but must be global in its pertinence. Moreover, we must recognize that only to the extent that it is a natural science of society does it stand a chance to succeed. Our special plea is that it be a science closely linked to the nature of the very earth itself including its spatial properties. . . .
>
> Social science and physical science are but mutually related isomorphic examples of one generalized logic. In both branches, many and diverse academic specialties can be recognized usefully in terms of content, but when patterns and relationships are investigated in terms of basic categories then the true unity of all knowledge is revealed. The more we learn of any pattern, the more we learn how much it is like some other. . . .

Warntz urges his listeners on to "that next necessary great advance of knowledge, a truly natural science of society," and concludes by

[2] Simon, *Models of Man,* pp. vii–viii.

asking: "And could not this advance be spearheaded by regional scientists and geographers?" [3]

On the applied level, urban and regional planners are becoming increasingly aware of the complexity of the social systems with which they are dealing. Demetrius Iatridis of the Athens Center of Ekistics has this to say:

> The increasing acceptance of social planners as full-status members in physical planning teams is the result of several crucial developments. One is the better understanding of the human settlement as an entity in its own right. Another is the increasing tendency to view it and the urban system essentially as individuals, groups, and social institutions in interaction with one another and as aspects of the societal systems. Experts in everyday practice were usually preoccupied with such elements as size, shape, density, stock of buildings or goods. But the recent emphasis on social interaction and social organization—the view that it is really the flow of information, goods, wealth or feelings among human beings in communication which comprises the human settlement—has resulted in an expansion of the physical planner's viewpoint. In practice, the planners' traditional and major foci of inquiry have grown; in addition to size, shape, land use, location and density, they are showing a keen interest in social organization, human interaction, social policy and social change. The study-focus of projects now includes a far greater number and scope of subjects and variables ranging from the political-administrative pattern of the human settlement to the essential behavioral patterns of individuals and groups.[4]

Additional evidences of the approaching convergence of other social sciences and economics are to be found in David Easton's systems approach to political life; [5] Hayward Alker's work on causal inference and political analysis; [6] the papers by Walter and Peter Isard on general social, political and economic equilibrium for a system of regions; [7] and the work of Brian Berry and others on the spatial aspects of human behavior in both urban and open-country environments.[8] The growing

[3] Warntz, William, "Global Science and the Tyranny of Space," *The Regional Science Association PAPERS*, Volume 19, 1967, pp. 7–19.

[4] Iatridis, Demetrius, "Social Scientists in Physical Development Planning: A Practitioner's Viewpoint," *International Social Science Journal*, Vol. XVIII, No. 4, 1966, pp. 474–475.

[5] Easton, David, *A Systems Analysis of Political Life*, New York, 1965.

[6] Alker, Hayward R., Jr., "Causal Inference and Political Analysis," pp. 7–43 in *Mathematical Applications in Political Science*, Vol. II, ed. by J. L. Bernd, Arnold Foundation Monographs XVI, 1966, Dallas, Texas.

[7] Isard, Walter and Peter Isard, "General Social, Political and Economic Equilibrium for a System of Regions: Part I," *Regional Science Association PAPERS*, Vol. XIV, 1965, pp. 1–33. (See also Part II in Vol. XV, published in 1965.)

[8] Berry, Brian J. L., *Geography of Market Centers and Retail Distribution*, Englewood Cliffs, N.J., 1967.

interest in political and social indicators in the United States will almost certainly foster attempts to find (or force) common denominators for measures of economic, social, psychological, and physical welfare.

Research by sociologists and political scientists on power structures in communities of various sizes and types suggests (to this writer, at least) that common denominators may be found for distributions of prestige and influence as well as those of income and wealth. The correlations among these distributions are high but by no means perfect. Power structures and other "mechanisms of influence" are being represented in terms of directed graphs and the corresponding matrices; so are other patterns of human interaction, as in formal organizations (firms, government agencies, and the like). At the level of measurement of individual behavior, the transactional analysis concepts of Berne and others, Roger Barker's concept of behavior settings, and the sociological concept of role playing provide elements ready for a tentative synthesis.

It may be noted in passing that hierarchies of central places (villages, towns and cities of different sizes) almost certainly reflect hierarchical patterns and tendencies within firms, agencies, and other organizations —tendencies that are perhaps too blandly subsumed under the general rubric of increasing returns to scale.

II

Measuring the Impact of Social Change on Individual Welfare

In a broad sense, society consists of patterned interactions among people. It would seem that the nature of an individual's participation in his society could be described partly in terms of the way he allocates his time among different kinds of interactions.

The social psychologist Roger Barker spent a good many years observing the behavior of residents of a small midwestern community of about 830 people. Barker[9] early addressed himself to the question of how the environment of human behavior was to be identified, described, and measured. He concluded that the community environment

[9] Barker, Roger G., Louise S. Barker and Dan D. M. Ragle, "The Churches of Midwest, Kansas and Yoredale, Yorkshire: Their Contributions to the Environments of the Towns," in William J. Gore and Leroy C. Hodapp (ed.), *Change in the Small Community: An Interdisciplinary Survey*, New York, 1967, pp. 155–189; and Barker, Roger G., "On the Nature of the Environment," *Journal of Sociological Issues*, Vol. 19, No. 4, 1963, pp. 17–38.

could be divided into parts or units which he called *behavior settings.* Barker says:

> Behavior settings are units of the environment that have relevance for behavior. They provide the primary data of the study to be reported here. We have dealt only with the settings that occur outside the homes of the community, that is, the public behavior settings. The number of public behavior settings in the town is a measure of the size of the town's public environment.
>
> We must emphasize that a behavior setting coerces people and things to conform to its temporal-spatial pattern. This is not an incidental or accidental characteristic. The person or persons who maintain and control the setting (the performers) make a deliberate effort to insure that this is so, and that the setting therefore fulfills its function. This aspect of a setting we call its *program.* Two settings are said to have the same program when their parts and processes are interchangeable. When this is true, two or more settings belong to the same *genotype.* Two grocery stores, for example, could exchange stock, personnel, bookkeeping systems, shelving, and so forth, with little interruption in their operation. They belong to the same genotype. A Methodist and a Presbyterian minister could, and sometimes do, exchange pulpits. The number of behavior setting genotypes in a town is a measure of the variety of the town's environment.[10]

Barker identified about 220 genotype settings in his town of 830 people. Examples include grocery stores, hardware stores, ice cream socials, kindergarten classes, business meetings, religion classes, hallways, bus stops, places of employment, one's own home, and many others.

Elements of Barker's more formal characterization of a behavior setting include the following:

It has a space-time locus.

It is composed of a variety of things and events: people, objects, behavior, and other processes.

The widely different components (of a particular behavior setting) form a bounded pattern, which is easily discriminated from the pattern on the outside of the boundary.

It is an objective unit, in the sense that it exists independently of anyone's perception of it, though not independently of the people who are a part of its pattern.

A behavior setting consists of both behavior and objects; both are essential; the setting is a phenomenon which consists of interdependent objects and behavior.

[10] Barker, *et al.,* "The Churches of Midwest . . . ," pp. 158–159.

An important factor is the space-time boundary; there is a physical boundary (for example, the walls and doors of a church) and there is a temporal boundary (for example, a service extending from 11 A.M. until 12 noon).

Within the boundary of the setting, the behavior of individuals conforms to the pattern characteristic of the setting. This fact is a function of other people in the setting and of the physical arrangement of the setting.

No behavior occurs outside of a behavior setting.[11]

When individual grocery stores, churches, and the like were recognized as separate or *specific* behavior settings, Barker found 884 public behavior settings in his town in 1963–64. He was able to record that the number of daily occurrences of behavior settings during 1963–64 was 53,258, and that the hours of duration of public behavior settings in 1963–64 totaled 286,909. Multiplying the hours of duration of each behavior setting by the number of persons participating in it, Barker obtained a record of "hours of occupancy" of behavior settings, totaling 1,129,295 in 1963–64. As there are 8,760 hours in a year, the total hours of "life lived" during the year by the town's 830 residents was 7,270,800. About 15 per cent of these hours were spent in public behavior settings (not counting, I believe, places of employment); the remaining "hours of living" were presumably spent in private homes, places of employment, and in transit from one behavior setting to another. For formal completeness, of course, we could say that each different kind of transportation between one locationally fixed behavior setting and another was itself a behavior setting (driving one's own car alone, riding with a car pool, walking alone, etc.).

It is tempting to apply the economic theory of consumption to Barker's data on the allocation of time, in the hope that this will lead to a more comprehensive measure of changes in human welfare than GNP.[12] On a purely descriptive level, the extent of the change in living patterns involved when a young man migrates from an agricultural village to a city could be illustrated in terms of the vectors of behavior settings occupied during his last year in the village and his first year in the city. His role in each behavior setting and the temporal rhythm of recurrence of settings are also aspects of welfare which will be mentioned shortly. For the moment, we shall explore the extension of consumption theory to the allocation of time.

[11] *Ibid.*, paraphrased from pp. 157–158.

[12] The present writer suggested this possibility to Barker and others at a symposium on "Change in the Small Community" in Chicago, October 24–25, 1966.

The Optimal Allocation of a Person's Time among Behavior Settings

How should an individual allocate his time among behavior settings? For a given individual, let

(1) $$v_i = a_i + b_i t_i, \quad i = 1, 2, \ldots, n$$

where v_i is the value derived per hour of time t_i spent in behavior setting i. Individual occasions (for example, a movie) might be "either/or" affairs, but over a year, the time spent in movies could be regarded as a continuous variable. Let

(2) $$W = v_i t_i = \sum_i a_i t_i + \sum_i b_i t_i^2$$

be a maximum, subject to

(3) $$\sum_i t_i = 8{,}760 \text{ hours per year.}$$

Then:

(4) $$\frac{dW}{dt_1} = a_1 + 2b_1 t_1 - \lambda = 0$$

$$\frac{dW}{dt_2} = a_2 + 2b_2 t_2 - \lambda = 0$$

$$\vdots$$

$$\frac{dW}{dt_n} = a_n + 2b_n t_n - \lambda = 0$$

Thus the conditions for optimal allocation of one's time among behavior settings are formally analogous to those for optimal allocation of a consumer's dollar income among objects of expenditure.

Also, if it costs money, p_i per hour, to occupy behavior setting i, the total money spent for (1) occupying behavior settings and (2) purchasing other services and goods g is subject to the budget constraint

(5) $$\sum_i p_i t_i + \sum_g p_g q_g \leq y$$

where y = money income. Place of work is included among the behavior settings and one *receives* a payment per hour for time spent on the job. The maximization of W implies an optimal allocation of time between labor and leisure.

For a poor man with expensive tastes, $v_i > p_i$ at the margin for all behavior settings occupied; if his money income were increased, his social income would increase, for he would spend more time in settings costing money. For a rich man, the time constraint would be effective but the money income constraint would not be binding; $v_i = p_i$ at the margin.

The system must include time spent by person j reading books by authors now deceased, painting pictures that may be viewed by persons yet unborn, or watching a specific television program or a category (genotype) of television programs.

In each behavior setting the person has a role—spectator, student, teacher, customer, salesman, committee member, or whatever. Whenever there are face-to-face interactions, mechanisms of influence in Simon's sense will be involved and "transactions" will take place (in the sense of Berne).[13] These micro aspects of interaction influence the amount of satisfaction a person gains per hour and the number of hours he spends per year in any particular behavior setting.

Extending the Time Allocation and Interaction Model to All Human Beings

We are concerned with world economic development and change. The concept of optimal allocation of a person's time among behavior settings could be extended to all human beings alive at a given time.

At present, the world's population is about 3.5 billion. To deemphasize the arithmetic, let us suppose that, world-wide, there are 4×10^9 people and 4×10^9 behavior settings, each home, store, etc. in the world being a different behavior setting. A complete matrix for recording the amount of time spent by person j with person k in behavior setting i, where $j, k, i = 1, 2, 3, \ldots, 4 \times 10^9$, would have 16×10^{18} rows and 16×10^{18} columns. The entries in the vast majority of cells would of course be zeros.

We have, however, a conceptual framework for allocating all the hours lived by 4×10^9 people during 1968 according to behavior settings occupied and persons interacting in each. In principle, we could measure the amount of time spent by each person j in receiving "information" from each other person k in each behavior setting i. However, the role played by person j in behavior setting i may be a more stable and meaningful aspect of his degree of satisfaction in that setting.

[13] Berne, Eric, *Games People Play: The Psychology of Human Relationships*, New York, 1964; and *Transactional Analysis in Psychotherapy*, New York, 1961.

Implicit in the behavior settings and interactions are places of employment and techniques of production, including staffing patterns and administrative organization of each enterprise. The equation system for all persons j could be constructed (or construed) to account for changes in the stock of physical capital, human (individual) capital, institutional and organizational capital ("going-concern" and "good will" values), and informational capital.

If this conceptual framework were used as a guide for economic development planning, additional information would be required, including: (1) attributes of each person, such as age, sex, occupation, education, nationality, language, religion, political party, and others affecting the selection of behavior settings and persons interacted with; and (2) exact geographic coordinates of each behavior setting, including homes, places of work, and "public" settings. These coordinates help to explain the spatial organization of economic and social life. Given 4×10^9 behavior settings, our geographic coordinates would enable us to calculate a matrix of "great circle" distances between settings (containing 16×10^{18} entries in all, or about 8×10^{18} nonduplicated entries). In principle, mileages by actual roads and commercial transport routes (land, water, and air) could be inserted in place of "great circle" distances. Reductions in travel times or travel costs between sets of behavior settings will increase the sizes of the geographic areas which are effectively integrated into communities, labor markets, urban fields, and commodity markets. Travel time and cost reductions will also give greater scope to economies of size in firms and public enterprises, leading to the emergence of hierarchies of central (urban) places that will accommodate larger organizations with more complex labor force structures.

With respect to any person j we may inquire whether the actual value of W_j in 1968 fell short of its potential and if so, to what extent. In other words could W_j have been increased by a different allocation of person j's time among setting-and-role combinations without reducing W_k for any other person k? An increase in the capacity of any person k to give (produce) human values *could* increase the welfare of one or more persons without reducing the welfare of other persons.

The gains from rearrangements within a given year may or may not be large. The potential gains from achieving an optimal pattern of investment in physical, human, organizational, and informational capital between (say) 1968 and 2000 should be enormous as compared with those from the tradition-limited patterns that have so far for the most part prevailed. To what extent can we identify, starting from 1968, a pattern of allocation of all human resources that would be optimal for the social and economic development of all mankind up to (say) 2000—an optimal deployment of human and physical resources for the achievement of human welfare?

The optimizing approach implies that all human institutions should be plastic and subject to planned or adaptive change to permit the expansion and enrichment of human awareness and interaction. Technological change would be valued to the extent that it made the world "a better home for man."

In the process of world economic and social development, the distribution of roles embodying economic, political, and social influence will undergo sweeping changes. As economists, we have been reasonably successful in measuring distributions of income and wealth. Power and prestige present, for us, novel problems of measurement.

Is there a common denominator for aggregating different kinds of influence? In a social system involving n persons, is there a "stock of influence" to be allocated among individuals according to the rank-size rule or some other regular principle? The rank-size rule would imply that, if the quantum of influence possessed by the most influential person is $I_1 = k$, the quantum of the second-ranking individual would be $I_2 = k/2$, of the third $I_3 = k/3$, and so on down to $I_n = k/n$ for the least influential person. The absolute differences among individuals in the lower half of the distribution would be rather small, ranging from $2k/n$ to k/n, while absolute differences among the top ten individuals would be large. Even granting this assumption, each subsystem in the society (and perhaps each behavior setting) might have its own rank-size rule operating among its own specific members or participants. If considerations of influence affected the utility of a behavior setting, each person would tend to allocate his time among behavior settings in which his situation in this regard was relatively satisfactory.

Eric Berne's concept of *recognition-hunger* seems less clearly asymmetrical as between persons and may be basic to the desire for any or all types of influence: "Each person becomes more and more individual in his quest for recognition, and it is these differentia which lend variety to social intercourse and which determine the individual's destiny. . . ." [14] Our approach in this section implies that an individual's sense of well-being depends partly on his consumption of purchased goods and services and partly on the allocation of his time among behavior settings in which he performs certain roles and receives (or per-

[14] Berne, *Games*, p. 15.

ceives) certain amounts of recognition. The change in the individual's circumstances from one year to the next could be measured in terms both of the goods he consumes and of the behavior setting, role, and recognition combinations which he experiences.

If a man moves from one town to another one at a considerable distance, but works at the same occupation and attends a church of the same denomination, his life pattern in terms of *genotype* behavior settings occupied may change very little. His roles and amounts of recognition in the *specific* new settings may differ from those in his former specific settings. On interview, he might be able to estimate how much money he would be willing to pay (or would require) to exchange each specific behavior setting in the new town for the corresponding setting in his former location, giving a common unit of measure to both the economic and noneconomic aspects of his move.

Arnold Faden has referred to the action of a person who changes (say) his residence but not his place of employment as "partial migration." [15] This term might be extended to any change over time in a pattern of behavior-setting occupancy. A change in role within a behavior setting might be similarly regarded. But if each "partial migration" in this sense can be equated with a compensating money payment, we can add the net gain or loss from "partial migration" to the net gain or loss in purchasing power, obtaining a dollar estimate of the total change in perceived welfare.

Space does not permit much further elaboration. However, a set of photographs of a typical young villager in each of his behavior settings, conveying an impression of his role and recognition in each, might be compared with a set of photographs of a young man of similar background occupying the settings and roles typical of those that the young villager might expect during his first and second years in the city. The technique could be developed to indicate, in film strips, the proportions of time spent in each setting and the sequences in which the settings occur, so that quantitative as well as qualitative differences would be observed.

Typical family adjustment problems could be visualized in this fashion, and so perhaps could the full array of problems of a representative sample of prospective migrants from villages to cities. The effects of alternative development strategies might be simulated in terms of the proportions of persons making specified changes or partially accommodating to change (for example, continuing to live in villages for some years while commuting by bus to factory jobs).

[15] Faden, Arnold M., *Foundations of Spatial Economics.* (To be published.)

III

The Urbanization Process: Rural-Urban Synthesis Around a National or Multinational System of Cities

If we really had all the entries filled in for 1968 in the 16×10^{18} order time allocation and interaction matrix described earlier, we should be able to identify the boundaries of a number of human organizations. The individuals belonging to a nuclear family and living in the same house could be clustered in such a way as to form a block diagonal matrix identifying individual families. Other patterns of behavior-setting occupancy by sets of individuals would identify villages and towns at different levels in the existing central-place hierarchy. Other patterns, very similar, except for the geographical proximity of the behavior settings, would identify neighborhood, community, and "regional" shopping areas within the larger cities.

Each of the human communities identified would be relatively self-contained with respect to a particular set of activities. In mainland China as of 1962 the rural commune was typically coextensive with the traditional administrative village or *hsiang*.[16] The *hsiang* (township) usually covered an area of twenty or thirty square miles, and it would require about an hour's time to walk from the center to the periphery of the area. In the United States as of 1911, C. J. Galpin found what he termed "fundamental agricultural communities" averaging about fifty square miles in area. These areas also required about one hour's time on foot or by horse and wagon to travel from the village center to the *de facto* community perimeter, a radius on the order of five miles.

Galpin described "the actual but unofficial community" which he found in Walworth County, Wisconsin as follows:

> Eight of the twelve civic centers of Walworth County are incorporated; four as cities and four as villages. Officially, that is legally, the incorporated centers are treated as communities, each by and for itself. The foregoing analysis of the use of the leading institutions of each center by the farm population discloses the fact, however, that these institutions are agencies of social service over a comparatively determinable and fixed area of land surrounding each center; that this social service is precisely the same in character as is rendered to those people—whether artisans, employees, or pro-

[16] Wang, Tong-eng, *Structural Change and Development in Chinese Agriculture*, unpublished doctoral dissertation, Iowa State University Library, Ames, Iowa, 1966.

fessional persons—who happen to live within the corporate limits of the city or village; moreover, the plain inference is that the inhabitants of the center are more vitally concerned in reality with the development and upkeep of their particular farm land basis than with any other equal area of land in the state.

It is difficult, if not impossible, to avoid the conclusion that the trade zone about one of these rather complete agricultural civic centers forms the boundary of an actual, if not legal, community, within which the apparent entanglement of human life is resolved into a fairly unitary system of interrelatedness. The fundamental community is a composite of many expanding and contracting feature communities possessing the characteristic pulsating instability of all real life.[17]

When Galpin began his survey in 1911, there were about 600,000 passenger automobiles in the United States. As of 1968 there are more than 60 million—an increase of at least a hundredfold! By 1968, the automobile was the almost universal means of shopping and home-to-work travel in the Midwest. There is conclusive evidence that the American Midwest can be delineated into a set of *functional economic areas* (FEAs) or commuting fields in terms of the patterns of home-to-work commuting from the peripheries of such areas to the central cities of (usually) 30,000 or more population at their centers. The speed of travel is ten times as fast as in Galpin's day; consequently, the radius of the fundamental community of 1968 is about fifty miles (instead of five) and its area is about 5,000 square miles (instead of fifty). Galpin's communities embraced 2,000 or 3,000 people; the functional economic areas of 1968 embrace from 100,000 to 200,000 or more people. Various terms have been used to describe the nature of these functional economic areas, including urban fields, commuting fields, labor market areas, and low-density cities. The functional economic area has also been referred to as "a new synthesis of rural and urban society." [18]

Toward the close of the "horse and buggy" era in 1911, Galpin described only one level of central place; his towns and villages ranged in population from about 500 to 3,000. The FEA in 1968 included at least three levels of fully viable central places, which Brian J. L. Berry has described as towns, cities and regional capitals. The typical populations of such places in western Iowa as of 1960 were about 1,500, 7,500 and 50,000 respectively. Functionally, these same levels can be discerned in

[17] Galpin, C. J., *The Social Anatomy of an Agricultural Community*, Madison: University of Wisconsin Agr. Exp. Sta. Res. Bul. No. 34, May 1915, pp. 16–19.

[18] Fox, Karl A., "Metamorphosis in America: A New Synthesis of Rural and Urban Society," Ch. 3, pp. 62–104 in William J. Gore and Leroy C. Hodapp (ed.), *Change in the Small Community*, New York, 1967.

metropolitan areas in the neighborhood, community, and regional shopping centers, respectively. The villages of less than 1,000 population in the American Midwest are rapidly declining in economic importance, and their Main Street establishments correspond to the scattered convenience shops found in the older sections of metropolitan areas.[19]

What Berry calls a regional capital, I have called the central city of an FEA. Berry recognizes two higher-order categories of central places, namely the regional metropolis and the national metropolis. These various orders of central places form a national system of cities; those of regional-capital (FEA central city) size or larger form the centers of urban commuting fields which, as of 1960, included some 96 per cent of the total population of the United States.[20] There are approximately 350 such FEAs or urban commuting fields in the United States.

The economic development of a large country may be thought of as the development of a national system composed of cities and their surrounding commuting fields. (The boundaries of the commuting fields are determined by the capabilities of the prevailing modes of transportation. In the United States the principal mode is the private passenger automobile. In other countries other modes of transportation range from slightly to vastly more important than in the United States. The boundaries of such commuting fields would tend to be fairly regular in terms of *minutes* of travel time required. In terms of miles, however, they might extend outwards for long distances from the central city along railroad lines, public bus lines, and well-paved highways. If bicycles or slower means of transportation were used from other peripheral areas, the commuting distances in miles would be much less.)

Berry has described the function of the national system of cities in the United States as follows:

1. We live in a specialized society in which there is progressively greater division of labor and scale of enterprise, accompanied by increasing degrees of specialization.

2. There is an increasing diversity of people as producers. But as consumers they are becoming more and more alike from one part of the country to another, consuming much the same "basket of goods" wherever they may live, as well as increasingly large baskets because of rising real incomes.

[19] Berry, *Geography of Market Centers,* p. 15.

[20] Fox, Karl A., "Functional Economic Areas and Consolidated Urban Regions of the United States," *Social Science Research Council ITEMS,* December 1967, Vol. 21, No. 4, pp. 45–49; and Fox, Karl A. and T. Krishna Kumar, "The Functional Economic Area: Delineation and Implications for Economic Analysis and Policy," *Regional Science Association PAPERS,* Vol. XV, 1965, pp. 57–85.

3. The physical problem in the economic system is therefore one of articulation—insuring that the specialized products of each segment of the country are shipped to final consumers, seeing that consumers in every part of the country receive the basket of goods and services they demand and are able to purchase, and bringing demands and supply into equality over a period of time.

4. Articulation requires flows of messages, of goods and services, and of funds. The flows appear to be highly structured and channeled and major metropolitan centers serve as critical articulation points. These flows are as follows: products move from their specialized production areas to shipping points in the locally dominant metropolitan centers; over the nation, products are transferred between metropolitan centers, with each metropolitan center shipping out the specialized products of its hinterland and collecting the entire range of specialized products from other metropolitan centers to satisfy the demands of consumers residing in the area it dominates; distribution then takes place from the metropolis to its hinterland through wholesale and retail contacts. In the reverse direction move both requests for goods and services, and funds to pay for goods and services received, so that the flows are not unidirectional.[21]

The principal railroads and highways planned for a large developing country should connect those central places (present or prospective) that are intended for its regional capitals and its regional and national metropolises. The integration of the presently rural or agricultural population with these regional capitals and larger cities is a problem for local planning and local transport system design.

In the United States each functional economic area or commuting field is currently a relatively self-contained labor market in the short run. The process of attaining maximum agricultural efficiency might be conceptualized as an iterative logical procedure along the following lines:

Starting with the existing labor force and stock of capital in each FEA, we might reallocate these resources within the area (a) to equalize the marginal value products of labor of any given quality among sectors and (b) to equalize the marginal value products of capital among sectors, agricultural and nonagricultural. We may partition agriculture and nonagriculture into as many subsectors as may be required to distinguish significant differences in production functions or processes.

If this initial reallocation were done on the assumption that the FEA is a "point economy," we might next let in real space and allow for the possibility that the marginal value product of labor of a given quality performed at a distance of fifty miles from the central city might be

[21] Berry, Brian J. L., "Approaches to Regional Analysis: A Synthesis," *Annals, Association of American Geographers,* Vol. 54, 1964, pp. 10–11.

smaller than the marginal value product of that labor applied in the central city itself. In other words, within the FEA we would expect to find wage and opportunity cost surfaces for each distinctive kind of labor. These surfaces would have their highest points *at* the central city and would slope downward with increasing distance *from* the central city.

The next logical step would be to compare the marginal value products of labor of given qualities *among* FEAs and also the marginal value products of similar kinds of capital. Then, using spatial-equilibrium concepts we might calculate a pattern for equalizing marginal value products among areas in order to minimize the social and economic costs of migration and capital relocation among FEAs.

Finally, we might consider an optimal pattern of organization in each FEA under present technology and make retraining of the local labor force an alternative to migration. Once again we would equate marginal value products across sectors within each FEA and (globally) among FEAs.

It must be stressed again that an FEA is a labor market area, urban and rural, agricultural and nonagricultural. If the United States should adopt an active labor market policy, it would be logical to try to maintain full employment *in each FEA*. Any worker who could not be employed in a "good" job in the FEA at a given time would be paid while engaged in additional training or retraining. Wages for agricultural workers under such a policy would have to be fully competitive with wages in other sectors of the area's economy at all times.

I mention the existing economic structure of the United States only as it may bear on development planning for countries presently less developed. In the United States the traditional dichotomy between urban and rural has largely disappeared. The city as an economic and cultural entity has surrounded the country. Farmers in most areas must now deal with an essentially urban market for labor, for capital and, increasingly, even for land.

If we refer again to the huge time allocation and interaction matrix we postulated, we may visualize the transformation of the spatial structure of Iowa from 1910 to 1960 as follows:

In 1910, the personal interaction patterns in Iowa's ninety-nine counties would have delineated well over 1,000 "fundamental agricultural communities" of the type described by Galpin. (Iowa has an area of about 57,000 square miles.)

In 1960, the interaction matrix would have partitioned Iowa into approximately twelve commuting fields, averaging about 5,000 square miles each. A careful classification of retail stores and service establishments in towns of different sizes and locations would also have indicated the existence of smaller trade areas averaging about one-fourth the size of the FEA and a set of still smaller trade areas averaging about one-sixteenth. Most of the towns of 1,000 population or less were no longer independent centers of economic activity but served as places of retirement for elderly farm people and as low-cost residential neighborhoods for persons working in larger centers.

In the United States as a whole, the number of "fundamental communities" must have declined from at least 30,000 in 1910 to about 350 in 1960. Transportation revolutions in developing countries may have similar effects. As of 1962, mainland China had about 75,000 rural communes, closely corresponding in number to the administrative villages (townships) of the former regime. Will another thirty years of development reduce the number of relatively self-contained labor markets to less than 1,000?

IV

Modeling Agricultural Production Within (a) FEAs and (b) Areas Based on Soil and Climate

Potential FEAs or urban fields in the less-developed countries should constitute logical units for forecasting the development of regional population and urban demand for agricultural products. A model such as J. A. C. Brown's could be disaggregated to the level of such urban-oriented areas. The set of areas would have to add up to the (multinational) regional total; consequently the system would also have to include any areas that represented gaps or interstices between the prospective urban fields. Very sparsely populated mountain and desert areas would be cases in point.

In the United States, total employment in an FEA can be divided into residentiary and export-oriented components. Under present conditions about 60 per cent of the employment in an FEA in the United States is in residentiary activities, such as retail trade, services, and local government. It is this writer's judgment that the residentiary labor forces of two FEAs of equal population are almost perfectly interchangeable. National chains of department stores and other establishments both recognize and reinforce this tendency. Regional and national firms engaged in planning shopping centers, schools, and other facilities also contribute to uniformity.

Export-oriented activities in a national system of FEAs must be defined with respect to typical areas of the FEA size and type. For this purpose, a large metropolitan area must be regarded as equivalent to the close packing of a number of "mononuclear" FEAs each with a population of 500,000 or less residing in the trade area of a regional shopping center. The relation between the locations of the residentiary employment and the export-oriented employment of trade area residents is complicated by the existence of freeways and rapid transit systems.[22]

All agricultural-production activities and all or most manufacturing activities would be classified as export-oriented in an FEA system. Consider an agricultural area covering perhaps 20,000 square miles and having relatively homogeneous soil and climatic conditions. Assume that one corner of this area is included within the commuting field of a rapidly growing city with a relatively high wage and salary structure. Suppose that another corner of the area is included in the commuting field of a city that is growing very slowly and has a considerable amount of low-wage employment. Finally, assume that the two cities are so far apart that the central portion of the agricultural area is at least two-hours' commuting distance from both of them.

Wage rates for hired farm labor (and opportunity costs of the labor of farm operators and their family members) would be high in the neighborhood of the rapidly growing city; lower in the neighborhood of the stagnating city; and considerably lower still in the area remote from both cities. As commuting from the remote area is not feasible, the only alternative to farming would be outmigration, most probably in the direction of the rapidly growing city.

Although soil and climate would permit the same range of agricultural activities in all three portions of the area, the opportunity costs of labor would differ widely. The optimal combinations of agricultural production activities in the three subareas might or might not be sensitive to these differences in the opportunity cost of labor; that would be a matter for empirical determination.

These considerations suggest a two-fold classification of agricultural regions in economic development planning. One set of regions would be distinguished on the basis of such characteristics as soil type, climate, terrain, availability of water, and the like. The other set of regions would

[22] A mononuclear FEA is one in which the commuting field is virtually co-extensive with the major retail trade or shopping area of the central city. See Karl A. Fox, "Strategies for Area Delimitation in a National System of Regional Accounts," paper presented at a joint meeting of the Committee on Regional Accounts and the Committee on Urban Economics, Los Angeles, California, January 23–26, 1968.

be the prospective FEAs or urban fields, with their prospective differences in opportunity costs of farm labor. Where these two types of area boundaries intersect there will be a larger number of segments than are included in either of the two basic sets. These segments could be aggregated within urban fields for some purposes and within homogeneous soil and climatic regions for others. The amount of data gathering and processing necessary to accommodate both sets of purposes should not be much greater than necessary to satisfy either one separately.

Recursive Programming Models for Homogeneous Agricultural Regions

Richard Day's recursive programming model of an agricultural area in the Mississippi Delta of the United States may well serve as a starting point for agricultural development planning in any subarea that is homogeneous with respect to soil types and climate and is wholly included within an existing or potential urban field.[23]

Day's model defines an array of production activities available for eight kinds of field crops in the Mississippi Delta between 1940 and 1958. With each crop the activities for application of fertilizer at three or four levels and on three different classes of land are defined. The activities are further defined for different technological stages. In the case of cotton, the first technology stage involves share-croppers, mules, and a sufficient acreage of corn to provide feed for the mules. A second stage includes light tractors and a third involves heavy tractors and four-row cultivating equipment. The fourth stage includes mechanical cotton-pickers, flame cultivators, and the use of chemical defoliants.

The model treats the entire cultivable area of the district (1,925,000 acres or 3,000 square miles) as though it were a single profit-maximizing unit. Each new technology comes into the optimal production pattern when it becomes sufficiently profitable relative to existing techniques. For example, as mechanical cotton-pickers were not commercially available before 1946, they were not permitted to enter the solution prior to that year.

Day's model predicts rather well the expulsion of unskilled labor from agriculture in the region, particularly after the advent of the mechanical cotton-picker; it also describes fairly well the year-to-year changes in acreages planted to the different crops.

The first development of such a recursive programming model for a particular agricultural region was a laborious task. The overhead costs

[23] Day, Richard H., *Recursive Programming and Production Response,* Amsterdam, Netherlands, 1963.

of programming and data organization might be reduced considerably if this approach were adopted for a comprehensive set of subareas in a national or multinational region. The initial demands for data may seem excessive in relation to the factual knowledge available in most of the less developed economies. However, the programming model gives a clear indication as to why the data are needed and what level of accuracy would be necessary to make practical distinctions between more and less profitable production activities.

The multinational regions described by J. A. C. Brown are of very large geographic extent, as the total land area of the earth (over 50 million square miles) is to be partitioned into not more than sixteen or twenty regions. The average area of such a region is as large as that of the continental United States. Earl O. Heady and his coworkers have used an exhaustive set of about 150 type-of-farming regions in a linear programming model of the agriculture of the United States. I have not examined the intersections of these 150 farming areas with the 350 or so functional economic areas delineated by Brian Berry. Juxtaposition of the two sets might lead to as many as 500 regions, for each of which a recursive programming model of agricultural production might be formulated.

Spatial-Equilibrium Models of the Agriculture of a Large Country or a Multinational Region

The solutions of such recursive programming models would provide estimates of the production of each agricultural commodity in each subarea, together with estimates of requirements for all inputs. At the same time, a consistent set of demand functions could be formulated for each agricultural commodity in each functional economic area or urban field.

Such a set of demand functions for twenty-four food products was developed by Brandow for the United States as a whole.[24] Because consumption patterns are quite similar over large regions of the United States, the same set of own-price and cross-price elasticities and income elasticities of demand could be applied without much inaccuracy to each of the individual FEAs. For computational purposes, the retail demand functions in each FEA could be approximated by arithmetic straight lines in the neighborhood of the existing price and consumption levels. The estimates of production of each agricultural commodity from the recursive programming models could be aggregated on an FEA basis.

[24] Brandow, George E., *Interrelations Among Demands for Farm Products and Implications for Control of Market Supply*, Pennsylvania State University, Agricultural Experiment Station, University Park, Pa., Bulletin 680, August 1961, see especially pp. 13–18.

If we recognized about twenty different agricultural commodities or commodity groups, we would have at this stage 350 arithmetically linear demand curves for each. We would also have estimates of the quantities of each commodity produced in each of the 350 areas. (Production of some commodities in some areas would, of course, be zero.) To effectuate a spatial-equilibrium model, we would need a 350 by 350 matrix of transportation costs between FEA central cities for each commodity.

If this level of detail for agricultural production planning seems excessive, two points should be kept in mind: (1) For some purposes, the 350 areas could be aggregated into a much smaller number of regions; (2) In a country with clearly marked climatic zones and soil areas, the great majority of the 350 areas will be either consistently surplus or consistently deficit with respect to any particular agricultural commodity for several years at a time. Hence, the structure of interregional price differentials for each commodity is likely to be remarkably stable, though it may be disrupted occasionally by a severe drought or other abnormality.[25]

Given the annual nature of most agricultural production, a set of spatial-equilibrium models within a multinational region could be thought of as a generalized cobweb model in which production in year t was treated as a function of prices in year $t-1$ and/or support prices and price expectations which were announced or formed toward the end of year $t-1$. The production of each commodity in each functional economic area in year t would then be taken as predetermined and the values inserted in the FEA demand functions. If the multinational region is considered to be a closed system, the combination of regional production, regional demand functions, and interregional transport costs would determine a set of market prices for all commodities in all regions, along with quantities consumed in each region and quantities shipped between all pairs of regions (again, many of these "shipments" will be zero).

Modeling Interactions between Agriculture and the Rest of the Economy within a Multinational Region

If our emphasis is on the agricultural sector, a highly aggregative model of the other sectors may suffice, as in J. A. C. Brown's scheme.

It is possible to arrange the sectors of an input-output model of the United States economy for 1947 (and presumably for later years) in such a way that most of the direct interindustry commodity flows are

[25] For elaboration of some of these points see Karl A. Fox, "Spatial Equilibrium and Process Analysis in the Food and Agricultural Sector," Chapter 8, pp. 215–233 in Alan S. Manne, and Harry M. Markowitz (ed.), *Studies in Process Analysis*, New York, 1963.

concentrated within four diagonal blocks. Thus, when the twenty-nine-sector input-output table presented by Chenery and Clark is used, the following set of sectors appears to be relatively self contained: fishing, apparel, leather and leather products, processed foods, grain mill products, textiles, lumber and wood products, rubber, chemicals, and agriculture and forestry.[26] Fishing could be excluded from this cluster if desired; the inclusion of lumber and wood products is necessitated by the fact that agriculture and forestry are combined in a single sector by Chenery and Clark.

Similar block diagonal concentrations can be shown for metals and metal products; petroleum and coal products, plus coal mining, petroleum and natural gas; and a group that includes nonmetallic mineral products and minerals, printing and publishing, and paper and paper products (plus industry not elsewhere classified).

The four remaining sectors, electric power, trade, services and transport, provide inputs to all or nearly all of the twenty-nine sectors, including agriculture. In an FEA system, most of the trade and service activities would be included within the residentiary sector, and a good deal of the fuel-based electric power might also be produced and used within the same FEA. Part of the transport activity is of a local character, but a substantial portion is intercity transportation and hence an integral part of the spatial-equilibrium system.

The structure of the input-output matrix just described suggests a number of implications for practical development planning:

(1) The residentiary components of services, trade (particularly retail trade), electric utilities, and local transportation systems should be designed in relation to the development plan for the residentiary sector of each FEA or urban field.

(2) Wholesale warehouses and intercity transport systems should be designed in relation to the planned and emerging system of FEA central cities.

(3) Preliminary development plans might be made for agriculture and forestry and for a set of closely related output-processing and input-supplying industries without too much regard for other industrial sectors.

(4) The preliminary plans for the agricultural and forestry complex could be brought into balance with preliminary plans for the other major industrial complexes in a second-stage calculation or planning operation.

(5) Although the major industrial complexes mentioned are relatively independent of one another as far as interindustry flows are concerned, they are definitely competitive for primary resources such as labor and

[26] Based on rearrangement of matrices in Hollis Chenery and P. G. Clark, *Interindustry Economics*, New York, 1959, pp. 220–230.

capital, and for foreign exchange to pay for imports. Levasseur, for example, has outlined a model in which the levels of output in each industrial sector, generated through an input-output model, are translated into demands for labor by occupation and skill category and the matrix of labor requirements then translated into a set of demands upon the educational and vocational training system.[27]

One could, of course, supplement an input-output flow matrix for a multinational region with a set of capital coefficients, as has been done by Adelman and others.[28]

The proposed recursive or dynamic programming model of agricultural production lends support to the notion of giving a mathematical programming formulation to the multinational economy as a whole. Programming models of national economies have been demonstrated by Adelman and Sparrow,[29] Hollis Chenery, Michael Bruno, and others.

The time-allocation and interaction matrix with which we introduced this paper also seems to call for a normative model of economic and social development planning with an objective function that has not as yet been satisfactorily specified. The "social indicators" movement in the United States and presumably in other countries is pressing social scientists to quantify such an objective function. As an intermediate step an objective function for a multinational region might be defined to include gross regional product, employment (or unemployment), a weighted combination of incomes of various occupational groups, an estimate of the increase in value of "human capital" resulting from education and training, and a (somewhat more speculative) measure of improved access to cultural and recreational services. The quality of life would be measured in part by the per capita forms of these variables.

V

A Model of the World Economy

For our present expository purpose, we will use one element of the objective function to stand for all of its components.

[27] Levasseur, Paul M., *A Study of Inter-Relationships Between Education, Manpower and Economy,* paper prepared for the U.S. Office of Education Symposium on Operations Analysis of Education, Washington, D.C., November 19–22, 1967 (mimeo.).

[28] Adelman, Irma and Frederick T. Sparrow, "Experiments with Linear and Piece-Wise Linear Dynamic Programming Models," in Irma Adelman and Erik Thorbecke (ed.), *The Theory and Design of Economic Development,* Baltimore, 1966, pp. 291–317. See also the comment by Karl A. Fox, pp. 317–326.

[29] Adelman and Sparrow, "Experiments . . ."

We assume that the world economy is divided into sixteen regions. We assume further that region A consists of the centrally planned economies (other than mainland China), region B consists of the industrialized economies not centrally planned, and regions 1–14 consist of regional groups of developing countries. Regions A and B are expected sources of grants, loans, and technical assistance to the other regions and, of course, are related to these regions through trade.

Possible objective functions for regions 1–14 as a group might be

$$\text{Max}\Delta U = \sum_{i=1}^{14} \lambda_i \Delta Y_i, \quad \text{Min}V = \sum_{i=1}^{14} \gamma_i (Y_i - Y_i^*)^2$$

subject to:

$$Y_A \geq k_A$$

$$Y_B \geq k_B$$

$$Y_i \geq k_i, \qquad i = 1, 2, \ldots, 14$$

where Y_i is the gross regional product (GRP) of region i; λ_i is a weight attached by a world policy-making body to a dollar of (increase in) GRP in region i; γ_i is a weight attached by a world policy-making body to squared deviations of actual GRP in region i from a growth path Y_i^* specified as optimal by that body; k_A, k_B and k_i represent minimum permissible levels of the GRP of the respective regions at any given time.

Time indexes and discounting factors are omitted from our notation; however, the variables and constraints should be regarded as applying to a target year (say 1978) or to each year t in a planning period of n years. For example:

$${}_{1978}k_A = (1 + e)^{10}\,{}_{1968}Y_A,$$

where e is the minimum acceptable annual growth rate for the GRP of region A.

Bases for Allocating Total Foreign Assistance among Regions

Assume for expository purposes that the increase in domestic investment-plus-foreign aid required to achieve a planned increase in the GRP of region i is a linear function of that increase in GRP:

$$(I_i^* + H_i^*) - (I_i + H_i) = b_i(Y_i^* - Y_i) \qquad i = 1, 2, \ldots, 14.$$

Suppose also that

$$I_i = c_i Y_i \quad \text{and } I_i^* = c_i Y_i^*.$$

Then $$(H_i^* - H_i) + c_i(Y_i^* - Y_i) = b_i(Y_i^* - Y_i)$$

and $$(H_i^* - H_i) = (b_i - c_i)(Y_i^* - Y_i) = d_i(Y_i^* - Y_i).$$

In the above expression, Y_i is the expected GRP of region i in the absence of foreign assistance and Y_i^* the desired value specified by a world policy-making body; c_i is a behavioral coefficient relating domestic investment I_i to GRP_i; and b_i is a coefficient depending on the economic structure of region i which relates a desired change in GRP to the total amount of domestic investment funds I_i plus foreign aid H_i necessary to accomplish this change.

If a regional policy-making body in region i applies relative weights w_{hi} to $(H_i^* - H_i)$ and w_{yi} to $(Y_i^* - Y_i)$, we have

$$H_i^* - H_i = d_i\left(\frac{w_{yi}}{w_{hi}}\right)(Y_i^* - Y_i); \quad \text{let } \beta_i = \left[d_i \frac{w_{yi}}{w_{hi}}\right].$$

Then for regions 1–14 as a group we may write

$$H^* - H = B\left[\sum_{i=1}^{14} \frac{\beta_i}{B}(Y_i^* - Y_i)\right]$$

where

$$B = \frac{1}{14}\sum_{i=1}^{14} \beta_i.$$

The relative weights or tradeoffs between an increase in GRP and an increase in foreign aid *might* vary from region to region.

If taken literally, the above formulation implies that the amount of foreign aid required in region i is a function only of the planned change in GRP in region i. As a matter of fact, all sixteen regions are linked through trade, so it appears intuitively that H_i^* will depend not only on Y_i^* but on Y_A, Y_B, and all the Y_j^*'s, where $j = 1, 2, 3, \ldots)i(, \ldots, 13, 14$. Recognition of these linkages in an operational way is possible only in a model which treats the world economy as a closed system.

Endogenous and Exogenous Variables in a World Model

A two-region example will illustrate the chief difference between an open model for a single region and a closed model for the world economy:

Region 1:

$$Y_1 = C_1 + I_1 + G_1 + E_1 - M_1$$

$$C_1 = c_1 Y_1$$

$$I_1 = i_1 Y_1$$

$$M_1 = m_1 Y_1$$

Region 2:

$$Y_2 = C_2 + I_2 + G_2 + E_2 - M_2$$

$$C_2 = c_2 Y_2$$

$$I_2 = i_2 Y_2$$

$$M_2 = m_2 Y_2$$

In region 1, we may (initially and naively) assume that E_1 (exports) is exogenous; G_1 (government expenditure) is our main policy instrument. Four variables, Y_1 (gross regional product), C_1 (consumption), I_1 (domestic private investment), and M_1 (imports), are regarded as endogenous.

In our two-region model, of course, $E_1 = M_2$ and $E_2 = M_1$, so the export variables become *endogenous* to the closed system, which may be displayed as follows:

"Leading" Endogenous Variable	Y_1	C_1	I_1	Y_2	C_2	I_2	M_1	M_2	E_1	E_2	G_1	G_2		
Y_1	1	−1	−1				1		−1		−1			0
C_1	$-c_1$	1	0		0									0
I_1	$-i_1$	0	1											0
Y_2				1	−1	−1		1		−1		−1		0
C_2		0		$-c_2$	1	0								0
I_2				$-i_2$	0	1							=	0
M_1	$-m_1$						1							0
M_2				$-m_2$				1						0
E_1								−1	1		0			0
E_2							−1			1				0

This display is not in conventional matrix form. The vector to the extreme left is simply a list to help the reader identify rows of the coefficient matrix with equations in the models for region 1 and region 2. The vector of ten endogenous and two exogenous variables, normally written as a column vector to the right of the coefficient matrix, is displayed as a set of twelve "column headings," each of which is to be multiplied by the coefficients in its column. Thus, the first row becomes

$$Y_1 - C_1 - I_1 + M_1 - E_1 - G_1 = 0,$$

or, rearranging terms,

$$Y_1 = C_1 + I_1 + G_1 + E_1 - M_1,$$

the first equation in the model for region 1.

In this system there are now ten endogenous variables and only two exogenous or autonomous ones, G_1 and G_2. Because of feedbacks through region 2, the multiplier effect upon Y_1 of an increase in G_1 is larger than if imports M_1 were a genuine and complete leakage from the economy of region 1. For example, let

$$c_1 = c_2 = 0.5,\ i_1 = i_2 = 0.2, \text{ and } m_1 = m_2 = 0.3.$$

If M_1 were simply a leakage, the multiplier in region 1 would be

$$\frac{\Delta Y_1}{\Delta G_1} = \frac{1}{1 - 0.5 - 0.2 + 0.3} = \frac{1}{1 - 0.4} = \frac{1}{0.6} = 1.67.$$

However, in the two-region system the corresponding multiplier becomes

$$\frac{\partial Y_1}{\partial G_1} = \frac{(1 - 0.5 - 0.2 + 0.3)}{(1 - 0.5 - 0.2 + 0.3)^2 - (0.3)^2} = \frac{0.6}{0.36 - 0.09} = 2.22.$$

If the policy maker in each region understands the structure of the complete system he will presumably take account of the fact that his multiplier is 2.22 rather than 1.67 in deciding by how much government expenditures should be modified.

A four-region model of the world economy opens up the problem of multilateral trade. If we express the G_i (government expenditures in region i) as functions of the Y_i, $i = 1, 2, 3, 4$ we obtain

$$\begin{aligned}
G_1 &= k_1Y_1 - m_{12}Y_2 - m_{13}Y_3 - m_{14}Y_4\\
G_2 &= -m_{21}Y_1 + k_2Y_2 - m_{23}Y_3 - m_{24}Y_4\\
G_3 &= -m_{31}Y_1 - m_{32}Y_2 + k_3Y_3 - m_{34}Y_4\\
G_4 &= -m_{41}Y_1 - m_{42}Y_2 - m_{43}Y_3 + k_4Y_4,
\end{aligned}$$

where

$$k_i = 1 - c_i - i_i + \sum_{\substack{j=1\\(i \neq j)}}^{4} m_{ji}; \qquad i = 1, 2, 3, 4.$$

Or,

$$\begin{bmatrix} G_1^* \\ G_2^* \\ G_3^* \\ G_4^* \end{bmatrix} = \begin{bmatrix} k_1 & -m_{12} & -m_{13} & -m_{14} \\ -m_{21} & k_2 & -m_{23} & -m_{24} \\ -m_{31} & -m_{32} & k_3 & -m_{34} \\ -m_{41} & -m_{42} & -m_{43} & k_4 \end{bmatrix} \begin{bmatrix} Y_1^* \\ Y_2^* \\ Y_3^* \\ Y_4^* \end{bmatrix}$$

or

$$G^* = (k - m)Y^*$$

where the Y_i^* are desired values of GRP and the G_i^* are the values of government expenditures needed to attain the Y_i^*.

Obviously, this model could be extended to any number of regions forming a closed system—one that includes the entire world economy. If our chief policy instrument is foreign aid, H, and if government expenditure from domestic revenues in each region i, G_i, is assumed to be a linear function of Y_i (say, $G_i = g_i Y_i$), we may write down the matrix equation

$$H^* = (k - M)Y^*,$$

where

$$k_i = 1 - c_i - i_i - g_i + \sum_{\substack{j=1 \\ (i \neq j)}}^{n} m_{ji}$$

and n is the number of regions into which the world economy is subdivided (in our opening example, 16).

The representation of international trade in this model is, of course, much too rigid, and the structures of the regional economies much too aggregative, for policy use. Brown's paper suggests the directions, though not the extent, of needed elaboration of the regional models.

A Detailed Model of the Agricultural Sector

We may recapitulate some of our earlier suggestions as follows:

(1) Expand the agricultural sector in each region into (say) twenty commodities or commodity groups; the same set of twenty must be used in all regions. (a) Represent consumer demand in each region by a Frisch-Brandow matrix, so that

$$f = Bp_o + \alpha + \gamma(y^{1*} - s^1 - y^{21*} - y^{A1*})$$

in each region; p_o is a vector of base-year prices. The variables in parentheses are defined as in equations 13 and 14 of Brown's paper.

(b) Add other domestic demands to household demand and specify a linear (or piecewise linear) function approximating total domestic demand for each commodity or group.

(2) Obtain regional supply functions and production estimates (S_{ij}) by various means depending on the data and research base available; assume the same base-year price vector p_o in estimating the S_{ij} as is used in estimating the quantities demanded for regional use (D_{ij}).

(3) Calculate exports, $X_{ij} = S_{ij} - D_{ij}$, where i ranges over fourteen less-developed regions plus regions A and B, while j ranges over twenty agricultural commodities. Here, S_{ij} denotes quantity of commodity j produced in region i and D_{ij} denotes quantity of commodity j demanded in region i.

(4) Calculate regional imports of *inputs* through an input-output matrix and regional imports of goods for consumption by means of demand functions, as proposed by J. A. C. Brown.

(5) Assume for the moment that exports go into, and imports come out of, a set of world "pools," one for each commodity.

We have discussed in Section IV the detailed structure (within a single large country or region) of a set of spatial-equilibrium models, with each year's supplies of agricultural products determined by means of recursive programming models for subregions. (Dynamic programming models might alternatively be employed for estimating supplies, depending on our purposes.) Also, we commented on the probable stability of the price structure of each agricultural commodity within a large country or region; "price structure" here referring to differentials among the prices prevailing at the different central cities of FEA or urban fields which constitute the emerging national or large-region system of cities.

So far, we have not discussed the possibility of exports from one multinational region to others among the sixteen, or the corresponding possibility of imports, at the appropriate level of detail.

If commodity price differentials between FEAs within each of the sixteen large regions are stable, it means that the price of a commodity in each of $n - 1$ FEAs will be a linear function of its price in the remaining FEAs. If a single currency is used throughout the region, and if transportation charges between all pairs of FEA central cities are fixed, a price increase of 10 cents per unit in one FEA should be accompanied by a price increase of 10 cents per unit in each of the other $n - 1$ FEAs. Also, if the demand function for a commodity in each FEA is linear, the change in the quantity demanded in each FEA is a linear function of the change in price. If the price in every FEAs increases by the same amount, the slopes of the demand functions in all n of the FEA can be added to give the slope of an aggregative demand function for the region as a whole.[30]

If such stability of price structures prevails within each region i, we can focus our attention on the prices of the twenty agricultural commodities at an FEA central city which is also a major seaport in region i or a major center for interregional trade by rail or motor transport. We need one such city in each of the sixteen large regions in order to complete our world model with respect to interregional trade.

If the proposed recursive programming models of agricultural production in subareas are realistic, the production response to a set of real base-year prices should make export surpluses available for some commodities in some regions at the base-year prices.

Then, given a set of transport costs between the selected port cities or other transport centers in each region, we could compute an optimal pattern of interregional shipments for each commodity and a resulting structure of price differentials for each commodity among the sixteen port cities. The effects of tariffs, subsidies and quotas maintained by any region or regions could also be taken into account in such a model.

The result (after some iterations) should be a price structure that integrates the internal small-area price patterns in each region with the pattern of price differentials among the sixteen regions, as reflected at their port cities. The sizes we have specified for potential FEAs or urban fields, and hence for agricultural production planning areas, would imply as many as 5,000 to 10,000 basic agricultural production programming units in the complete model of the world economy emphasizing agriculture.

A Two-Level (World and Regional) Model for the Allocation of Foreign Aid and Technical Assistance

In a very different context, Francis P. McCamley has combined the two-level planning model of Kornai and Liptak and the decomposition principle of Dantzig and Wolfe.[31]

For our present purposes, we assume seventeen "teams" of development planners, one each for the sixteen world regions assumed and one representing a world-level policy-making body.

Some of the resources available to each region i are locationally spe-

[30] See Fox, Karl A., "Spatial Price Equilibrium . . . ,"
[31] McCamley, Francis P., *Activity Analysis Models of Educational Institutions,* doctoral dissertation, Iowa State University, Ames, Iowa, 1967.

cific to that region and are allocable by policy makers in that region. In any given year, each resource of this type is subject to a capacity constraint. Hence, the set of inequations in a mathematical programming model of each region's economy would lead to sixteen diagonal blocks in a complete model of the world economy. In view of the preceding section, however, the fact that some resources are locationally specific is consistent with the existence of a large amount of interregional trade in the inputs and outputs of production activities in the various regions.

In addition, we assume the existence of a particular set (vector) of resources that are suitable for foreign aid and technical assistance, including assistance in developing the agricultural sectors of all regions. Each of the potential foreign aid and technical assistance resources is regarded as a world pool; each of these resources H_j, $j = 1, 2, \ldots, m$, is to be allocated among the i less-developed regions, $i = 1, 2, 3, \ldots, 14$, *and* regions A and B.

We must ascribe to the team representing a world-level policy-making body an objective function which permits it to "price" units of all outputs in all regions in a common currency. Ideally, this function would include both economic and noneconomic aspects of human welfare, as implied in Section II.

An iterative process could be carried out between the world-level policy-making body and the regional teams. For any *tentative* set of allocations of aid resources H_{ji} to region i, region i would compute optimal internal adjustments and report back to the world-level team. The world-level team would then revise its allocations, and each regional team would again compute its optimal internal adjustments. The final result of the iterative process should be an allocation of foreign aid and technical assistance resources that would equate the marginal value products of each foreign assistance resource among all of the sixteen regions, as viewed in terms of the objective function of the world-level policy-making team.