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EMPIRICAL VERIFICATION IN ECONOMICS: CLASSIFICATION AND AGGREGATION

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PART I

EMPIRICAL VERIFICATION IN ECONOMICS: CLASSIFICATION AND AGGREGATION

CHAPTER I

I. INTRODUCTION

1. Purpose, Method, Scope, and Significance of the Study

A. Purpose

This study aims at evaluating the methodological significance of the processes of classification and aggregation in economics as an empirical science. The working hypothesis of the study is that classification of things and processes is a necessary bridge between the realm of theory and that of empirical phenomena.

Theory must provide categories to which facts are assigned. This amounts to a classification of facts in accordance with some theoretical criterion (or criteria). A classification is said to be coarse or fine depending upon the degree of aggregation imposed upon its elementary categories. When two or more categories are combined into a new one, it is said that they are aggregated, or that aggregation has occurred within the model to which they belong. Conversely, when a given category is decomposed into two or more new categories, it is said that disaggregation has occurred. Thus aggregation is a specific aspect of the more inclusive problem of classification. This study examines both these problems within a unified framework.

B. Method

The method of this study consists in focusing on two selected theoretical systems in economics, namely, those of Keynes and Leontief, utilizing them as specific mediums for the study of the general problem of classification and aggregation. However, before imbedding it in these analytical frameworks, the problem is studied from the broader methodological viewpoint of empiricism in economics and in other sciences. Biology and psychology are selected for the purpose of comparison with economics, while focusing on the question of classification.

Also, the literature on classification and aggregation in input-output analysis was critically reviewed to bring together some of the essential results within a unified theoretical scheme. This was deemed necessary because the ideas in this field are badly scattered and have not been systematized in a single work so far. This critical survey is a happy by-product of the investigation of the general purpose of the study referred to above.

Therefore, the method of this study involves elements from at least three distinct methods of inquiry: analysis, interdisciplinary comparison, and critical survey.

C. Scope

Classification schemes applied by data recording agencies in business and governmental organizations are not examined in this study. Only those of scientific orientation are considered.

The study was originally intended to include an investigation of the former as well. But the ensuing research revealed that this would unduly enlarge the scope and, further, would require essentially different approaches. Therefore, without denying the importance of the problem it was decided to eliminate it from the study in order to delimit the scope, allowing for a more comprehensive treatment of the subject within the more restrictive scope.

On the theoretical side, the problem of aggregation from micro- to macro-variables and relations was left out of consideration. This type of aggregation has attracted some interest in recent years. It is, however, an essentially different notion of aggregation from the one associated with the problem of classification in this study. The former accepts the prevailing "micro-macro" distinction in the methodology of economics, while the latter, proceeding on more fundamental fronts, questions the theoretico-empirical significance of this distinction.

It is true that the two could be given a unified treatment from the standpoint of the purely formal features of the mechanics of aggregation. But since the mechanics of this problem is of minimal and incidental interest to the study as a whole, it seemed appropriate to omit the aforementioned type of aggregation from the domain of inquiry.

The scope of this study is further restricted by excluding all considerations related to normative economics. Only the domain of positive economics is explored. By positive economics the author understands the systematic study of what, how, and why economic phenomena occur the way they actually do. By normative economics, on the other hand, is understood considerations of what, how, and why certain economic activities ought to occur.

The justification for this restriction of the scope--in addition to the sheer need to delimit the investigation in order to concentrate efforts more intensively in a specified area--is that normatice economics is heavily dependent on positive economics in its method of analysis. Positive economics can stand by itself; normative economics cannot. Therefore the investigation of the methodology of positive economics, to the extent that the analytical engine of positive economics is shared by normative economics, automatically covers some aspects--of the purely analytical character--of normative economics. However, there are, needless to say, many problems as well as analytical methods that are not shared by the two.

D. Significance

The perpetual interplay of theory and fact constitites the very essence of the methodology of empirical sciences. Investigation of facts suggests theories, and, in turn, theories enable the scientist to seek new facts.

In economics these two inseparable poles of scientific work are utterly separated with consequent detrimental effects to the discipline as an empirical science. Contrary to the predominant view, econometrics cannot be expected to eliminate this problem. The question is not the devising of more efficient and sophisticated statistical techniques, but one of the general orientation of theoretical models in economics.

An empirically oriented model should provide within itself sufficient qualitative differentiation--or, in technical terms, a sufficient number of distinct variables--to enable it to reflect the essential features of the empirically differentiated reality. Models that are constructed in terms of few highly aggregative variables would necessarily and unduly suppress many of the qualitative differences that are actually observed. Econometrics cannot be expected to reverse this process of suppression of qualitative differences, a task which is not even necessary if the methodological problem involved is recognized by the theorist in the first place. Methodological shortcomings of economic theory cannot be compensated for by more improved statistical techniques.

It is, therefore, necessary to investigate the methodology of economics from the standpoint of empirical implementability of economic models and theories. The problem of classification and aggregation is found to be of strategic importance in such an investigation.

A methodological study of this type is also urgent because of the impressive success of some of the large-scale linear models such as input-output and linear programming models as theoretic-empirical constructs, and the need for knowing the reason (or reasons) for such success. It may be that economic theory as a whole can learn from the experience of these offshoots on its sides.

The critical survey of the problem of classification and aggregation in input-output analysis mentioned in section B is another aspect of the significance of this study. This part of the study was not a separate task but one which was found to be of great convenience as a concrete medium for the study of the more abstract methodological considerations mentioned above. But it was also significant by itself since no work of its kind was available on the subject, most of the ideas being scattered in various references in the form of isolated monographs at various levels of sophistication. Often various formal, mathematical tools applied by different authors give the impression that there are essential differences in the economic content of their works. It was necessary to clear away some of these difficulties by means of a uniform theoretical frame and formal technique.

2. Some Observations of Interest on the Development of Economic Thought

Medieval economics concerned itself with one or another aspect of economic life in isolation from the rest. For example, their doctrine of just price and their views on interest are instances of the moral-legal approach which was characteristic of the period.

Nor was this treatment--in isolation and on noneconomic grounds--of economic problems as irrational as it may seem today. Economic problems of the time, at the level perceived by the pamphleteers of this period, could be treated in isolation from the rest of the economy because the component parts of the economy itself stood in an isolated, and more or less self-sufficient relation to one another. Economic interdependence existed only to a very meager extent. Thus the economy could not be conceived of as a whole, because it was not a whole. The word "system"--so much in use today--could not be meaningfully applied to such an economy, as far as the specific problems of price, interest rate, etc., were concerned. This was so because there did not exist a developed market for goods or capital in order to tie the various rates of interest or various prices into an interrelated network. The role of market was thus not as essential as that of customs, traditions, moral dictums, etc., in establishing prices of goods and factors.

Economic interdependence evolved on the basis of progress in the division of labor as it interacted with the size and operative efficiency of markets. The development of the "home market" as a result of a rather advanced degree of progress in the division of labor was the most important vehicle of unifying the individual parts of the economy into an integrated whole--into a system. In place of loosely structured empires there arose the modern states characterized by a high degree of internal cohesiveness reflecting the high degree of economic interdependence among its regions, productive activities, etc. This objective cohesiveness was expected to lead to a corresponding subjective cohesiveness--the phenomenon of national ideology in the modern state.

This process impressed itself upon the minds of the thinkers of the period. Political theories of the national state evolved rapidly, beginning with this period. In economics, the response to the "wholeness" of the economy found its most clear expression of the writings of mercantilists. Mercantilism is essentially economic nationalism.[1]

Mercantilists saw the strength and prosperity--as conceived by them--of the state in the acquisition and accumulation of gold. They proceeded to formulate policies--not always wrong--towards this end. The ultimate justification for these policies was the power of the state,

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[1] Such broad generalization are necessarily open to questions unless one proceeds to specify in detail precisely what is meant by "economic nationalism." This shall not be done here. However, in the context of broad historical review intended in this section such generalizations cannot always be avoided.

which would be enhance, they held, by means of acquisition and accumulation of gold.[2]

The point to note is that mercantilists were the first to make the notion of the economy-as-a-whole a central feature of their arguments. Prices and foreign trade were to be manipulated in such a way that the <u>system</u> would respond in a given desirable manner. Thus, mercantilists differ from the medieval writers on economic subjects in that they saw the economy as an integrated whole. But they were similar to the medievalists in that they thought that the economic process can and should be manipulated in such a way that it can better conform to their ends. They did not see the system as a "natural" entity with its own "self-regulative" internal mechanisms or "laws of motion."

The physiocrats not only saw the economy as a "natural system" with determinate (and determinable) laws of operation, but also they proceeded to specify their own view of what these "natural laws" were. It is said of Quesnay, the leader of the physiocracy and originator of the <u>tableau economique</u>, that he, being a physician, was inspired by William Harvey's discovery of circulation of blood, thereby developing his model of "circulation of wealth." Regardless of the truth of this proposition, Quesnay's tableau presented a picture of the economy characterized by a fixed pattern of operation. He, for the first time in

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[2] The following is a comprehensive treatise on mercantilism: E. F. Heckscher, <u>Mercantilism</u>, ed. E. F. Sonderlund, rev. ed.; London, 1955.

economics, made the notion of interdependence of the system a central feature of his work.

The economy was conceived as being composed of three classes: the land-owning class, the farmer (peasant) class, and the class of artisans. The tableau was a hypothetico-numerical specification of how the annual product of the two classes of farmers and artisans is circulated and diffused among the three classes.[3]

The notion of structure as an <u>invariant</u> pattern of interrelationships among certain components of the economy is a major contribution of the physiocrats. It did not emerge as a central characteristic of a theoretical system in economics until recently when Leontief gave it a prominent position in his scheme. It is to be noted, however, that although the Leontief's model shares with the <u>tableau economique</u> of the physiocrat the <u>formal</u> feature of abstracting an invariant pattern of interrelatedness from the complex processes of economic life, the concrete natures of the two models differ in a fundamental way. The classification scheme of Quesnay's tableau is "coarse," that is its elements

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[3]For an interesting and simple interpretation of the <u>tableau economique</u> see Shigeto Tsuru, "On Production Schemes," Appendix A, in Paul M. Sweezy, <u>The Theory of Capitalist Development</u>, New York: Monthly Review Press, 1942, pp. 365-374. A detailed discussion of the significance of the tableau may be found in Ronald L. Meek, "Problems of the <u>Tableau Economique</u>," in James A. Gherity (ed.), <u>Economic Thought: A Historical Anthology</u>, New York: Random House, 1965, pp. 115-149; the tableau is interpreted as a simple Leontief model in Almarin Phillips, "The Tableau Economique as a Simple Leontief Model," quoted in Gherity, pp. 150-158.

are broad aggregates, such as "farmers," "artisans," etc. The basis of classification is not a more or less simple, unique principle. The distinction between the three classes are based on what they produce--as in the case of farmers and artisans--or on whether or not they own property, or on the type of property held--as in the case of land and non-land property. Leontief's "structure," however, has a "fine" classificatory scheme, its elements being much smaller parts of the economy than, say, Quesnay's "artisans." Here the elements are industries, defined as a group of producing units (not necessarily firms or even establishments) that produce essentially the same product. This is not a mere difference of degrees, one between a more aggregative and less aggregative formulation of the same concepts. There does exist a qualitative difference: Leontief's scheme abstracts not structure *per se* but rather the *technological structure* of the economy. This abstraction would not have been significant if it were not for the fact that Walras had already established the fact that "equilibrium" prices and outputs of various commodities can be deduced once technology, tastes, and resources are specified. These three sets of data will be referred to as the *fundamental economic data.*[4]

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[4]A simple mathematical formulation of Walras's model is provided in Chapter III. For a detailed, essentially non-mathematical discussion see Joseph A. Schumpeter, *History of Economic Analysis*, ed. Elizabeth B. Schumpeter, New York: Oxford University Press, 1961, pp. 998-1026.

Following the physiocrats, Adam Smith saw the economy as a system with inherent "natural laws" that guaranteed its smooth functioning. The motivating force of the social mechanism was announced by Smith to be the self-interest of individuals participating in economic activity. He emphasized the importance of non-interference with the natural course of economic events as automatically directed by the market.

Smith and his followers were primarily interested in the factors that determine the overall performance of the economy. In today's parlance, the classical school was primarily interested in macroeconomic problem. The economy was conceived as a system with a definite mode of operation and internal <u>structure.</u> The mode of operation of the system consisted of the competitive process through which individuals would offer their resources to earn an income which would in turn be offered to get commodities for consumption or investment. The structure of the system was conceived of in terms of ownership criteria: laborers own no property and receive only wages, land owners receive rent and owners of capital receive profit. Further, no explicit "collusions" were to exist among the members of each of these three classes and the ownership of property was not to be concentrated to such an extent that would eliminate effective competition in the market.

Ricardo developed some of the ideas with regard to the structure of the economic system which were present in a more or less embryonic form in Smith. He actually suggested that the "laws" that regulate the distribution of income among the three social classes constitute the subject matter of political economy.

Now, whatever the justification for this conception of structure, referring to today's borderlines of sciences, this conception and its implications (which were extensively brought out by Marx and other socialist writers) involves elements from at least three distinct scientific disciplines: political science, sociology, and economics.

This conception of the "economic" structure of society--whether or not useful in the frame of a more comprehensive social theory--is not of much value to the economic science for the following reasons: (1) The categories of this conception, land, labor, capital, rent, wages, and profit, consisted of such heroic aggregates of qualitatively different entities that any theories applying to them would of necessity be suppressive of a great deal of empirical differentiation actually observed. For example, land is conceived of as a homogeneous whole, with no distinction as to location, fertility, etc. The same can be said with respect to the treatment of labor and capital.

Such a high degree of abstraction, which treats empirically heterogeneous wholes as homogeneous ones, has limitations on two distinct but related levels:

i. theoretical reasoning; and

ii. empirical implementation of theoretical propositions.

Both these points are extensively examined throughout this study from several different angles. Suffice it to say in these introductory comments, that even a most elementary departure from such aggregative thinking in the case of land--the distinction between lands of different qualities--led to the formulation of the celebrated theory of "diminishing returns" as the most universal "law" of the neo-classical economics. Both theories of value and theories of production share the same formal character of "diminishing returns."[5]

There is no doubt that for "specific purposes" any degree of abstraction or aggregation is permissible. The justification for such aggregation lies in the efficiency with which the specific problem at hand is analyzed with the help of the aggregative categories introduced. But when aggregations in the grand style--land, labor, capital--constitute the fundamental elements of a science, the situation is different. The rich qualitative variety of the empirical world is suppressed in favor of simplicity in analysis. But, as Chapter VII shows, together with such simplification in analysis, many problems to be analyzed ceased to be problems within the framework of the "simple,"

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[5] For a most comprehensive evaluation of the nature of the "law of diminishing returns" and its role in economics see K. Menger, "The Logic of the Laws of Return: A Study in Meta-Economics," in Oskar Morgenstern (ed.), Economic Activity Analysis, New York: John Wiley and Sons, 1954.

aggregative formulation. They must be formulated separately within the frameworks of other theories. For example in a one-industry general equilibrium model of the economy[6] the problem of bottlenecks in production cannot be formulated; it is aggregated out of the model by regarding all different industries as one aggregated whole. Thus one result of aggregative formulations is the restriction of the domain of phenomena that can be analyzed by means of the related theoretical constructs. This simplification in analysis is achieved at the expense of the problems to be analyzed.

On the empirical side, the farther removed a given category from the observed things and processes, the less definitive the nature of that category. For example the category "industrial equipment" is much more definitive than "capital." As a result, aggregative theoretical formulations lead to empirical "indefiniteness" and result in theories that cannot be easily confronted with reality. Hence a serious departure from the fruitful methodology of science--which demands that theories be kept in check by means of direct or indirect empirical verification--is introduced as a result of aggregative formulations. Unfortunately this state of affairs characterizes the present day economics no less than that of the Ricardian era.

(2) The classical conception of "economic" structure was

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[6]Most "Keynesian" general equilibrium models have this type of formulation.

fundamentally a sociologically oriented one: its elements were the social classes. It is true that these social classes entered the economy in different capacities and with different functions. But they could not serve as useful categories, say, in the determination of prices of commodities and productive services, as the classical theory of value aspired to do. An ideal theory of value must provide a formal framework for the determination of different prices for different commodities and productive services. Not price of capital goods in general but the price of specific types of capital goods, not wages in general but specific wages, this is the formulation that is needed for an empirically verifiable theory of value. Further, the observed inderdependence of the various parts of the economy dictates that simultaneous determination of magnitudes be adhered to.

Economics had to wait for the application of the theory of simultaneous equations by Walras before it made any significant use of the idea of simultaneity corresponding to the widely recognized feature of interdependence in the economic system. But it should be remembered that the idea of simultaneity was a central feature of Quesnay's *tableau economique*. In the absence of the mathematical tools of simultaneous equations a flow diagram, such as that used by Quesnay (or the tabulation corresponding to it), is the best available means of displaying interdependence among the component parts of a system. Unfortunately, this important contribution of the physiocrats did not find any enthusiastic response among economists[7] except for Marx who rescued Quesnay's tableau from anonymity (in his Theories of Surplus Value, Vol. IV, Capital); much later Leontief set to construct an empirical tableau economique for the United States economy.[8] Simultaneity in the determination of economic magnitudes, whether expressed by means of a system of equations, the loops in a flow diagram, or a tabulated algorithm describing a method of successive approximations to the true solution, all these various analytic techniques correspond to the objective phenomenon of interdependence within the economic system. It was the great merit of Quesnay's tableau to have provided the first analytical scheme to reflect this objective interdependence in some essential way.

The Walrasian system was the first comprehensive system of interrelated, well-defined economic magnitudes which allowed for a high degree of qualitative differentiation within the formal context of a theoretical model in economics. The elementary concepts of the model were distinct commodities and productive services. The elementary relations involved were the supply and demand relations for various commodities and services. The economic science had come a long way

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[7]The work of Cournot and Walras was considered as esoteric sidetrack by most economists well into the second quarter of this century. Further, except for the generic feature of simultaneity, there is little resemblance between Quesnay's tableau and, say, Walras's system of equations.

[8]See Wassiley Leontief, The Structure of American Economy, 1929-1939, New York: Oxford University Press, 1960, p. 9.

since the time of the medieval pamphleteers: the economy was conceived of not as a conglomeration of isolated units but as a well-integrated, cohesive system of interrelated parts. A formal analogue of the system was developed whose elements were not the herotic aggregates of Quesnay or Ricardo but the simple, immediately given, concrete notions of specific commodities and productive services. Thus corresponding to the observed <u>empirical differentiation</u> the Walrasian system displayed a comprehensive <u>formal (or theoretical)</u> differentiation, bringing economic theory closer to the immediately given reality. This was a decisive step toward the development of economics as an empirical science. This feature of theoretical differentiation to correspond to the observed empirical differentiation of reality was to become a central feature of Leontief's input-output analysis. Such a parallel between a theory about reality and reality itself is of utmost methodological significance. It is brought out in several different contexts in the following chapters.

The Walrasian system was regarded by him, Pareto, and others as being of purely theoretical interest. The reason given was that the number of distinct equations corresponding to distinct commodities and services was so large that the solution of the system of equations would be actually impossible. With the modern computers being almost a century away, this computational difficulty alone was sufficient to support the view that the system was of a formal character and could not be implemented empirically.

There is, however, another fundamental feature of the Walrasian system which tends to move it away from the immediacy of concrete reality, thereby rendering its empirical implementation difficult (and perhaps impossible). This aspect of the problem has not been explicitly brought out in the literature as far as this writer has been able to determine. Its immense methodological significance demands that it be studied at some length. Chapters II and III provide a full presentation of the problem under the generic term of "invariance." Here the problem shall be introduced only in general terms:

The elementary relations of the Walrasian system consist of the supply and demand relations in the market. The demand for and supply of each commodity or productive service is expressed as the function of all other prices, with resources, tastes, and technology entering as data in a parametric capacity. Thus the focus of attention in the Walrasian scheme is the exchange process. In a market economy the exchange process is characterized by a high degree of instability. In statistical terms, though there may be an actual empirical relation of demand for a given commodity, the distribution of this relation around its norm--assuming that there exists one--tends to have a large variance. The inherent instability or large variability of the market relations of supply and demand is derived from the very function of the exchange process in a market economy: the exchange process directs the production and consumption patterns of society by virtue of its instability, its continual disturbance of equilibrium values, directing the system toward a new set of equilibrium values only to be disturbed before even they are arrived at. A perpetual negation of existing magnitudes and relationships is the very essence of the dynamic process of exchange in a market economy. Therefore, though at any instant of time there does exist an empirical set of interrelated supply and demand relationships in the market, so volatile are these relationships that they are not observable immediately and their determination is no easy statistical task as the "identification problem" in econometrics reminds everyone. In other words the structure of these interdependent magnitudes which consists of the set of all relations involved is in a state of flux because the elementary relations themselves are in a state of perpetual motion. This fluidity and volatility of the relations and of the consequent structure render the empirical specification of this structure an almost impossible and, even if possible, useless task. This is so because invariance--relative stability of the parametric structure of a set of relations--constitutes the very kernel of the concept of "order" or "law" in nature.[9] Since the structure of the Walrasian system is inherently unstable, it follows that, even if it is specified for a given period of time, it is not of much use because it will not reveal any

[9]This point is fully developed in a section on "invariance" in Chapter III.

"order" or "law" in the above sense. Various aspects of this question are studied in Chapter III.

Compared to Quesnay's tableau, the Walrasian system was a step forward not only because of the mathematical rigor applied in the formal specification of the model, but also--and very importantly--as already noted, because of its avoidance of aggregative formulations and allowance for a high degree of qualitative differentiation.

But in so far as the stability (and therefore empirical observability in a direct way) of the relations involved is concerned, Walras took a step backward from Quesnay: Quesnay's structure of the economy consisted of a more or less invariant pattern of interrelationships that tied the three rather stable social classes of artisans, land owners, and farmers together into a relatively fixed network, or pattern. Once this pattern is empirically specified then it is of value because it changes only slowly in normal times. The full assimilation of the notion of invariance into a comprehensive economic theory was achieved for the first time by Leontief in his construction of the American input-output table of 1919 in the 1930's, followed by almost a whole new sphere of economic analysis by Leontief and his coworkers on the Harvard Economic Project, and extended over a number of decades.

Following the formal demonstration by Walras that all prices and quantities of commodities and services in the economy can be deduced from the set of fundamental data--preferences, technology, and resources, --Leontief set to determine the "structure of the economy" by direct observation of the fundamental data themselves rather than going through the intermediacy of market relationships.

Leontief's formal model is based on an input-output table. The ij th cell of th table measures the amount of output of the ith commodity or service absorbed in the production of the j th commodity. Thus the entries in the j th column would be measures of the various inputs necessary for the production of output of the j th commodity. If these entries are expressed as a percentage of the total output of j, then they would measure inputs of various types per unit of output of j. These percentages are referred to as "coefficients of production" by Leontief. The set of all the production coefficients in an economy constitutes the structure of that economy. The various versions of the model, open, closed, static, dynamic, and combinations of these, enabled Leontief to separate the more stable and easily accessible relationships and data from the more variable ones, the focal point of attention being the specification of a relatively stable structure that would reflect the complex network of interrelationships in the economy. Such a structure emerged as a result of the application of his open static model which primarily concentrated on the "technological structure" of the economy.[10]

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[10]Chapters IV and V describe this model and the notion of technological structure in detail.

Leontief's model synthesized the disaggregated formulation of the Walrasian scheme with the notion of invariance implied in Quesnay's tableau. Whereas the elementary categories of Walras, being specific commodities and services, constituted immediately observable things or processes, his elementary relations, far from being directly observable, had a high degree of variability and, therefore, undesirable for an empirically-oriented theory. The elements of the system consisted of the categories of commodities and services on the one hand, and the supply and demand relations on the other hand. However, only the former were immediately given and directly observable. The latter were not. Leontief devised his system in such a way that all its elements--categories as well as the relations among these categories--were of an immediately given and directly observable character.

Hence the Leontief scheme is the culmination of a slowly developing trend in the economic science involving the notions of "system," "simultaneity of relations" (corresponding to the empirical interdependence of the economy), "structure," and invariance. The direct line goes through Pareto and Walras to Quesnay. Leontief is an offspring of the great Lausanne school.

Though there has developed a great deal of interest in the Leontief's scheme in recent years, many economists continue to regard it as an incidental offshoot of the economic science and very few schools even introduce it to their students at the undergraduate or even graduate level. Much of the interest in input-output analysis is concentrated in the area of construction of input-output tables or the analysis of problems within this framework. Works that would put input-output analysis in a proper perspective in relation to the rest of economic theory are rather scarce.[11] Much more scarce (and perhaps non-existent) is a systematic study of the methodology of input-output analysis. Such a study is significant because input-output analysis is, so far, the only theoretical construct in economic which has closely adhered to the scientific method whereby theories are required to be confronted with facts in order to be accepted or refuted. Throughout this study the importance of adherence to the scientific method is emphasized and the methodology of economic is examined to see in what ways, if any, it departs from the scientific method in general. The focal question is whether or not economics is an empirical science and if so what are the methodological criteria to which it should adhere.

It will be shown in Chapters II and III that classification of objects and processes is a necessary bridge between the world of abstract

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[11] Other than Leontief's works, systematic attempts to present the theory of input-output analysis are limited to the following:

(1) Hollis B. Chenery and Paul G. Clark, Interindustry Economics, New York: John Wiley and Sons, Inc., 1967.

(2) R. Dorfman, P. A. Samuelson, and Robert M. Solow, Linear Programming and Economic Analysis, New York: McGraw-Hill Book Co., Inc., 1958.

(3) William H. Miernyk, The Elements of Input-Output Analysis, New York: Random House, 1965; this is a very elementary introduction to input-output analysis.

(4) Shiou-Shuang Yan, Introduction to Input-Output Economics,

theory and concrete empirical reality about which a theory is presented. The question of classification and the related notion of aggregation (disaggregation) where a classificatory scheme is transformed from a finer (coarse) into a coarser (finer) one assumed a central position in the discussion of the methodology of economics as an empirical science. The by-product of this general methodological review (and criticism) of economics is the more specific treatment given to two prevailing macro-economic systems: those of Keynes and Leontief. Being concerned with the empirical contents of these models the study reviews not only the formal models but their underlying social-accounting schemes as well. Some generalizations emerge out of this comparative study in Chapters IV, V, VI, and VII.

Further, since the problem of classification and aggregation in the input-output framework has, so far, been discussed in few scattered papers, it seemed essential to give it a more systematic treatment in the setting of a broader framework of methodology and analysis--a task which could not be expected from the treatments in papers and symposium discussions which usually restrict themselves to very specific aspects of a given problem.

New York: Holt, Rinehart, and Winston, 1969.

3. The Economic Science and its Environment

In the preceding section it was seen that the economic science, like other sciences, almost leads a life of its own; it grows and develops. The distance travelled from Quesnay's to Leontief's tableau is an impressive instance of such growth. It is essential, however, to remember that a science grows within and in response to the needs of a definite social milieu. Thus economics, like any other science, necessarily interacts with its environment; changing and being changed by it. A discussion of some specific instances of this interaction may help explain some of the shifts of emphases or reorientations that have occurred in the science since its early days, and throw light on its present state or some evolving orientation in near future.

Some general remarks regarding economics of the medieval period and its relationship with the medieval economic environment were made in the beginning of the last section. The same was done with respect to mercantilism and physiocracy. The following discussion begins with the classical period.

The classical school assumed that a market economy has a natural tendency towards full employment. Every supply was necessarily matched by effective demand since money earned in production is only good for spending: money is a mere medium of exchange. This argument, more rigorously formulated as the "Say' law of markets," is too well known to need a detailed discussion here. The point to note is that this assumption of the classicists was a "natural" one reflecting their experiences. Cyclical patterns and prolonged periods of significant unemployment of resources did not appear as a problem of concern until the second half of the nineteenth century. Since full employment could be assumed as a "natural" state of affairs, the economist's attention was directed toward the patterns of overall output or its composition.

The classical dynamics with its component theories of population and diminishing returns on land, exemplified in the theory of the Stationary State, illustrates the preoccupation of the classicists with the overall patterns in the economy--the macroeconomic problems. The neo-classical school, still assuming full employment, concerned itself with the problem of the composition of social output, leaving aside questions of a macroeconomic character.

However, there was little justification for the neo-classical assumption of full employment, because by now the picture of the economic environment had changed significantly, and unemployment occurred recurrently and intensely. Only lack of originality and insistence on pedantic endearment of the older theories could explain the adherence to this unrealistic assumption.

Even in their formal analysis the neo-classical economists had little new to offer. They could do no better than "discovering" (? !)

that the law of diminishing returns is really not restricted to land but that it is a universal economic law governing not only production but also consumption. However, the neoclassical school should be credited for paving the way for the development of praxeology through its reliance on the notion of economic rationality. Some of these developments will be reviewed in Chapter III. As a whole the neo-classical school was not responsive to changes in the actual economic environment about which it theorized.

The methodological influence of the neo-classical school consisted in (1) channeling economic analysis into a qualitative path, and (2) introducing pure deduction and axiomaticism throughout the domain of economic inquiries. Both these tended to retard the development of economic as a quantitative empirical science. Chapter III examines these points in some detail.

Because of its non-empirical orientation, (and the consequent lack of response of their theories to the changing conditions in the economic environment), the neo-classical school was vulnerable to the Keynesian assault, specially since the latter was launched precisely at the time when there were ample objective grounds for rejecting the full employment assumption of the former.

Keynes attacked the classical assumptions of full employment, flexibility of wages and prices, and Say's law, as if these had always been unrealistic. In reality the world about which Keynes theorized was a different one than that of the classical period. Certain institutional changes had brought about "stickiness" of wages and price, demand for "money to hold," etc. Thus Keynes's attack on Marshall and other neo-classicists was as justifiable as his attack on the classicists was unjustified. It was only the former who had failed to realize the changed conditions of economic life, thereby failing to adjust their assumptions and theories accordingly. In the case of the classical school, Say's law, and flexibility of prices and wages were reasonably realistic assumptions, approximating reality of the period rather closely.

The depression environment of 1930's provided a fertile ground for a rapid popularization of the Keynesian theories. There occurred a shift of emphasis from questions related to the <u>composition</u> to those of the <u>level</u> of output.

The exceedingly rapid recovery of the American economy as a response to the war-induced demand in the late 1930's and early 1940's once more posited the problem of composition of output at the center of economic investigation. The rapid change in the composition of demand which was the result of transition from a peace to a war economy during the early phases of economic mobilization, necessitated a systematic approach to the problem of bottlenecks in production. Such a systematic investigation would have to proceed within a detailed, empirically implementable framework which would reflect the quantitative interdependence of various industries. An input-output table for the economy as a whole or for the strategic parts would do precisely this. Thus the economic problem of transition to a war economy provided an environment extremely favorable for the development of input-output analysis.

There were, of course, many other institutional and environmental changes that led to the emergence and growth of linear economics in general and input-output analysis in particular. A few of these are examined in the last section of Chapter II and in Chapter III. Briefly, the increasing complexities in the directing and management of governmental, business, and military organizations have stimulated interest in the development and application of quantitative optimization models. A whole new science of Operations Research with heavy reliance on the techniques of mathematical programming has evolved. The performance of the postwar economy at a level reasonably close to full employment has tended to give new impetus to the study of the composition of output. Also many economists have mastered the tools of mathematics and statistics and insist on a quantitative approach to economic problems, regarding the qualitative Marshallian analysis and the method of partial equilibrium rather outdated and inefficient.

The generic features of linear programming and input-output analysis on the one hand, and the wide use of the former at the establishment, firm, or industry level and of the latter at the economy-wide level, on the other hand, lead to the prognostication that soon the two may be synthesized to give a comprehensive numerical analogue of the economy. This synthesis, if it comes, will make the immense wealth of technological and accounting data of productive units of the economy immediately available to the economic science. A revolution in the economic science will occur!

The development of large scale electronic computers was the sine qua non of practical application of the aforementioned linear systems in economics. The development of more detailed and also more comprehensive economic models will accelerate as the presently occurring computing revolution speeds up its spiral path. Simulation of economic systems will put the powerful method of experimentation at the disposal of economists. Professor Morgenstern has aptly referred to computers as the telescope of economists.[12] Just as the inventions of telescope and microscope were essential to the development of astronomy and biology, the inventions of analogue and digital computers are expected to accelerate the progress of economics as an empirical science. Since the role of computers and some of its possible impacts on the economic science have been dealt with in extenso by Professor Morgenstern in an article mentioned in the last footnote, this aspect of economic empiricism is not treated in any detail in this study; only

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[12] Oskar Morgenstern, "Experiment and Large Scale Computation in Economics" in Oskar Morgenstern (ed.), Economic Activity Analysis, New York: John Wiley and Sons, Inc., 1954, pp. 540-541.

scattered references may be found. This should not give the impression that this writer discounts the significance of this development. It is impossible to do so for anyone who has read the immensely important and interesting article just mentioned.

Since the mathematics and also the computation techniques of linear systems is much better understood than those of the non-linear systems, it is expected that much of the development in near future in economics will concentrate in the area of linear models and theories. Thus the era of non-linear economics, with its spectre of diminishing returns which has haunted the science since the first quarter of nineteenth century, is expected to come to an end. But "diminishing returns" like an old soldier never dies; it fades away.[13] Chapter III examines some aspects of non-linear theories in economics.

The practical possibility of computing large systems of equations removes all the justification of over-aggregative, not to say super-aggregative, formulations in economics. This is a profoundly important observation, in spite of its obviousness. Unfortunately the traditional practice continues to appear in textbooks and the majority of articles currently published. Hence the science progresses at a

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[13]This deliberately hyperbolic statement may be misleading. In Chapter III it is noted that the "law of diminishing returns" as a specific hypothesis may be very useful and even operationally significant. It is the universalization of it as a fundamental theoretical statement underlying virtually all of economic theory that is objectionable in this writer's opinion.

rate below its optimal rate because of the force of habit and lethargy due to tradition. Such a non-optimal performance is not very becoming of economics since this is the discipline that has explored the "principle of rationality" most systematically; and the notion of optimum was developed by this science first. Economics should apply some of its prescribed medicines to itself!

4. Outline of the Study

Methodological considerations on empiricism are essential to the entire study. Chapter II sets forth some basic concepts in epistomology and methodology of empirical sciences. The problem is examined more concretely in the latter part of the chapter by means of drawing examples from developments in biology and psychology. An outline of the scientific method is provided.

Chapter III applies some of these concepts to economics. It studies several aspects of the method of economics in relation to the problem of empirical implementation of economic models and theories.

With Chapter IV the analytical part of the study begins. The social accounting bases of the Keynesian and Leontief models are treated within a more inclusive scheme of which these two constitute special cases. The fundamental identities of each of the two accounting systems are developed.

Chapter VIII presents a disaggregative monetary model involving notions of sectoral velocities of money and sectoral transactions balances. Some problems of empirical verification of this model as well as the direction of widening the explanatory scope of the model are investigated.

Chapter IX provides a synthetic overview of the whole study and presents some concluding remarks.

CHAPTER II

INDUCTION: AN INTEGRAL COMPONENT OF THE SCIENTIFIC METHOD

The problem of classification and aggregation in economics is essentially a methodological one. It arises in relation to observation of economic phenomena and also in relation to verification of economic theories through the confrontation of the theorems deduced from the postulates of the theory with the observed phenomena. In either case observed objects and processes must be organized into classes. The conceptual counterparts of classes of things and processes are called "categories."

The full significance of the problem of classification and aggregation cannot be grasped unless it is embedded into the more general framework of the scientific method as a whole. In this chapter, therefore, an outline of the scientific method as popularly recognized and exposed by scientists and/or philosophers of science, will be presented. Particular emphasis, however, will be put on the role of induction and its associated procedure, classification, because it is this aspect of the methodology of economics that has been persistently ignored or approached improperly.

In order to keep the discussion concrete, some fields of science are selected in relation to which the general discussion of methodology proceeds. These are biology and psychology.

Biology is selected primarily because it exemplifies, more clearly than other sciences, the method of induction. Other reasons for this choice will be found in the following sections.

Psychology is used because, with its deductively formulated theories, it has in common with economics the feature that its empirical base is quite narrow. Strictly speaking, this remark is meaningful only with respect to the Freudian theories and the modifications thereof. Other reasons for selecting psychology will be given as the section is introduced later in this chapter.

After the method of induction with its component parts, observation and classification, is studied <u>in concreto</u> by means of specific examples drawn from sciences, a more abstract treatment of the scientific method will be presented, which will summarize the methodological content of the chapter and also introduce deduction and reduction as modes of inference that together with induction constitute the method of science. This chapter provides the basis for evaluation of the method of economics and a critical examination of the problem of classification and aggregation which constitutes the main theme of the present study.

Throughout this chapter the distinction between the readily-available-and-observed facts and experimentally-derived-and-observed facts is suppressed. This distinction, while significant in a specific discussion of the method of science is of no particular value for a more general level of discussion which is followed in this chapter. The suppression of this distinction in no way alters the results of the following arguments. Therefore, the word "observation" refers to facts regardless of whether these were gathered from nature or were produced by experiments. If the distinction becomes important in a given context it will be introduced explicitly.

1. Goals of Science

Human specie has the most widespread geographical range among all living beings. This is the result of his ever-increasing ability to adapt to most varied environments through the application of such means that would enable him to survive and propogate. The most fundamental of these means are those related to the production of food and shelter.

Men produce their food, shelter, and objects of their cultural needs. Production is the key to human survival. Production is a means of transforming the "thing in itself" into a "thing for us." The "neutral stuff" of nature--matter, energy, conditions, and relationships, of which man is provisionally unaware and which affect him neither favorably nor unfavorably--are transformed into objects of utility.[1]

But the "rules" of this transformation are not arbitrary:

> Physical reality is at all times the basis on which human culture rests. The physical environment, appraised both quantitatively and qualitatively and viewed as changing relationships of trends and forces rather than as static conditions, therefore, is at all times the foundation of human productive effort. Arts, no matter how highly developed, and wants, no matter how urgent or sophisticated, are helpless in a vacuum. Without acting on and drawing from physical nature they are unproductive. To know, however, what particular opportunities a given physical environment has to offer at a given time and place, one must first learn what man <u>can</u> and <u>wants</u> to do with it.
>
> <u>Nature sets the limits within which man can develop his arts to satisfy his wants.</u> Within these limits he is free to select from the myriad of possibilities offered by nature those which at a given time and place promise the best results in terms of want satisfaction in return for the human effort applied thereto.[2]

The forces and conditions of nature present man with innumerable barriers against the satisfaction of his wants. The neolithic man had to accept these forces and conditions just as the animal kingdom does. He was not free with respect to the laws of nature. Human history began, one may speculate, with the discovery that mechanical motion can be transformed into heat: the production of fire by friction. The discovery of the wheel, metals, domestication

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[1] Eric W. Zimmerman, <u>World Resources and Industries,</u> rev. ed.; New York: Harper and Brothers, Publishers, 1951, pp. 8, 12, 14.

[2] <u>Ibid.</u>, p. 11.

of animals, agriculture, the steam engine, and electricity were but a step forward in civilization, a stride towards human freedom from the forceful and blind laws of nature. This freedom does not consist in the dream of negating the laws of nature but in the knowledge of these laws. According to Hegel freedom is the appreciation of necessity. "Necessity is blind only in so far as it is not understood."[3] (emphasis added, M.M.)

To understand natural laws means to know a set of tendencies about one or more aspect of nature.[4] Without understanding the laws of nature, man is ignorant of nature's resources. "Knowledge is truly the mother of all other resources."[5]

Human society is a part of nature. A systematic study of human society is expected to lead to the discovery of the tendencies existent in it in a given historical epoch. Humanity is powerless against the force of the tendencies internal to it--forces that result from the social mode of existence of men--as long as the nature and causes of these tendencies are not understood. Social existence of

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[3] Frederick Engles, Herr Eugen Dühring's Revolution in Science, New York: International Publishers, 1966, p. 125.

[4] "Nearly all laws of science are statements of tendencies." Alfred Marshall, Principles of Economics, 9th ed.; New York: The MacMillan Company, 1961, I, Text, 31.

[5] Zimmerman, p. 10.

men implies the existence of a network of interdependencies among men--a network which is in a continual state of flux with ever increasing complexity. The fact that this flux of interdependent relationships has as its atomistic components some elements of human consciousness manifested by individual, purposeful acts, rational decision making, and some degree of freedom as to the choice among a set of alternatives, does not imply that the overall social tendencies consist of a consciously-designed path collectively desired by men. The overall tendencies that emerge on social level are the resultant of a very large number of individual tendencies and conflicting forces.

These tendencies exist both as a result as well as inspite of individual human action. They become impersonal, and objective laws of human society--similar to the laws of nature in general--even though the participants consist of subjective elements, i.e., human individuals. It is this objectivity of the social process that justifies the existence of social sciences.[6]

Some laws of nature are more complex than others. In the case of such laws there exist a large number of factors that influence the course of a given process. Hence the degree of exactitude achieved by science in relation to these laws is less than that achieved

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[6]On objectivity of social phenomena see Max Weber, "Objectivity in Social Sciences," Reading in Philosophy of Science, ed. Philip P. Wiener, New York: Charles Scribner's Sons, 1953, pp. 325-339.

for less complex processes. Laws of nature that involve men are among the most complex laws.[7]

Science is thus a means to understand nature and enable man to choose freely from the offerings of the nature he knows. The understanding of human social environment is just as important as that of his physical environment. Thus social freedom--freedom related to the "socialness" of man--is dependent upon the development of such an understanding. Knowledge is the sine qua non of human freedom.[8] Hence, science aims at understanding not only physical nature but human society as well. Through science man increasingly narrows the realm of necessity and widens the realm of freedom.[9,10]

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[7]On a comparison of natural laws and economic laws see Marshall, I, 29-37.

[8]Determination of the ultimate goals of science necessarily involves value judgment. However, the futility of the argument of "science for science's sake" has been fully exposed by Tolstoi. Unfortunately no reference is readily available to the author who, on a different occasion was exposed to Tolstoi's work in this area. It is thought that the reference, incomplete as it is, should be made because of the importance of work.

[9]"Necessity" and "freedom" are applied here in the Hegelian sense as discussed above.

[10]Some observers advance the view that knowledge must be acquired for its own sake. Marshall writes that "economics has . . . as its purpose firstly to acquire knowledge for its own sake, and secondly to throw light on practical issues." But it can be argued that "science for its own sake" has little justification. Unfortunately an examination of this point would necessitate a lengthy digression which is not appropriate here. However, see footnote 8, above.

In the study of nature and society a set of approaches have evolved--though not definitive and final--which may be referred to as the "scientific method." An outline of this is needed for the study of some methodological question of interest in economics.

2. Method of Sciences

In 1937 Leontief wrote that "interest in methodological problems has so often been branded as a sign of theoretical frustration that the subject has practically vanished from the field of economic discussion."[11] Yet a showdown between the various schools and trends in the economic science must be fought on methodological grounds.[12]

Methodology consists of the study of method. Lange writes that

> method in the general sense of the word means a mode of behavior (i.e., a definite sequence of actions) employed regularly, consciously, and purposively. A method is thus a set of means which are used in a given

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[11]Wassiley Leontief, The Structure of American Economy, 1929-1939, New York: Oxford University Press, 1960, p. 58.

[12]In his brilliant criticism of the "neo-Cambridge school" in The Structure of American Economy, 1929-1939, Leontief showed the shaky methodological foundations upon which Kahn's "ideal output," Robinson "efficiency units," Hick's "elasticity of substitution," and Keynes's "aggregate demand and aggregate supply" concepts rest. Today, in 1969, these concepts are no less prevalent in economic theory than in 1937 when Leontief wrote his essay. See, for example, Allen, R. G. D., Macroeconomic Theory: A Mathematical

> way to obtain a certain end. Scientific method is a special case of the study of method in its most general meaning, since scientific investigation is a human activity with the definite aim of acquiring knowledge about reality and the laws by which it is governed.[13]

Any discussion of the method of sciences necessarily involves a concept of reality and some notions as to the process of human cognition, that is, the area known as epistomology in philosophy.

A. Epistomological Considerations

For some philosophers reality is but the manifestation of the "Idea," the perfect "form" of which the empirically observable thing is a more or less imperfect manifestation (Plato). Thus every individual chair embodies "chairness" as its "essence."

Hegel saw history as the unfolding process of "Reason." In "Idea" or "Reason") all reality has "its being and subsistence."[14] Thus, the "substance" of the universe consists of consciousness.

For other philosophers consciousness is not independent of objective reality; it is rather a more or less abstract reflection of

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Treatment, New York: St. Martin's Press, 1968; and Hans Brems, Quantitative Economic Theory: A Synthetic Approach, New York: John Wiley and Sons, Inc., 1968. Both these authors devote substantial effort to develop the last three of the above concepts.

[13] Oscar Lange, Political Economy, General Problems, trans. A. H. Walker, New York: The Macmillan Company, 1963, I, 100.

[14] Morton Donner, K. E. Eble, and R. E. Helbling, The Intellectual Tradition of the West: Copernicus to Kafka, Dallas:

this reality. The British empiricist school[15] definitely follows this line of thought.

Bacon (1561-1626) wrote that "man, as the minister and interpreter of nature, does and understands as much as his observations on the order of nature, either with regard to things or the mind, permit him, and neither knows nor is capable of more."[16]

Thus for Bacon human consciousness is an imperfect reflection of nature whose existence is independent of human awareness of it.

Further amplifying this mode of thought Hume (1711-1776) developed his theory of the process of cognition:

> Nothing, at first view, may seem more unbounded than the thought of man, which not only escapes all human power and authority, but is not even restrained within the limits of nature and reality. . . .
>
> But though our thought seems to possess this unbounded liberty, we shall find, upon a nearer examination, that it is really confined within very narrow limits, and that all this creative power of the mind amounts to no more than the faculty of compounding, transposing, augmenting, or

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Scott, Foresman and Company, 1968, II, 318.

[15] Among the foremost members of this school were Bacon, Hobbs, Locke, and Hume. See Joseph A. Schumpeter, History of Economic Analysis, New York: Oxford University Press, 1961, pp. 120-126. Here Schumpeter erroneously leaves Bacon out!

[16] Francis Bacon, Novum Organum, Great Books of the Western World, Chicago: Encyclopedia Britannica, Inc., 1952, XXX, 107.

> diminishing the materials afforded us by the senses and experience. . . .[17]

This "empiricist" pattern of thought has become an essential component of scientific, as well as the general, outlook of men to the extent that "it is with some difficulty that we understand the possibility of another mode of approach to the problem of nature."[18]

At the threshold of the modern era there occurred a most uncompromising assault on rationalism[19]--the legacy of the scholastic doctors.[20] A firm belief in the independence of nature from the thoughts of men was both a precondition as well as a by-product of the growth of science. This was but the philosophical counterpart of the growing knowledge of man about nature. As such, it could not but grow side by side with this knowledge. In fact, the separation of

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[17]David Hume, "An Inquiry Concerning Human Understanding," Donner, Eble, and Helbling, p. 183.

[18]Alfred North Whitehead, Science and the Modern World, New York: The Macmillan Company, 1948, p. 62.

[19]Schumpeter defines rationalism as follows: ". . . the belief not only that our mind is the source of truths that are antecedent to experience, but also that our mind is able to produce results about supermundane subjects, such as existence of God." Schumpeter, History of . . . , p. 113.

[20]Schumpeter's term, Ibid., p. 73.

science and philosophy occurred only much later in history. The great men of "the century of genius"[21]--the seventeenth century--simultaneously engaged in scientific as well as philosophical enquiry. Kepler, Galileo, Pascal, Newton, Locke, Spinoza, and Leitbnitz are only a few of a long list of the vanguards of the modern era.

B. Induction and Deduction

On the methodological front induction was presented as an alternative to deduction in the study of nature. Bacon had a prominent role in this. Whitehead remarks that:

> The explicit realization of the antithesis between the deductive rationalism of the scholastics and the inductive observational methods of moderns must chiefly be ascribed to Bacon; though of course it was implicit in the mind of Galileo and all the men of science of those times."[22]

Newton clarified his empiricist position by advising inference from experiments not from suppositions:

> . . . Since the qualities of bodies are only known to us by experiments, we are to hold for universal all such as universally agree with experiments. . . . We no other way know the extension of bodies than by our senses, nor do these reach in all bodies; but because we perceive extension in all that are sensible, therefore we ascribe it universally to all others also. . . .[23]

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[21]Whitehead, p. 57.

[22]Ibid., p. 62.

[23]Isaac Newton, "Mathematical Principles of Natural Philosophy," Donner, Eble, and Helbling, p. 132.

This shift of emphasis from deduction based on arbitrary hypotheses to induction based on detailed observations of nature revolutionized not only the concept of reality held by men but also their method of comprehending reality. In words of Bacon: "The signs for the interpretation of nature comprehend two divisions, the first regards the eliciting or creating of axioms from experiment, the second the deducing or deriving of new experiments from axioms. . . ."[24]

Bacon's empirical method actually consists of three parts: observation, description, and classification. Empiricism begins with immediately apprehended fact and ends with described facts.[25] Facts in these two senses must not be confused. Only fact in the former sense is fact independent of all concepts and theory. Described fact is fact brought under concepts and to this extent under theory. Furthermore, "described fact is not a mere aggregate of atomic data. One inspects relations as well as sense data. Consequently, described fact takes on the form of propositions" i.e., expressions of which it is significant to say that they are true or false.[26]

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[24]Bacon, p. 140.

[25]F. S. C. Northrop, The Logic of the Sciences and the Humanities, New York: The Macmillan Company, 1948, p. 35.

[26]Ibid., pp. 35-36.

Collection and description of facts is an important step in science. This stage of scientific inquiry is called the natural history stage by Northrop.[27] The methods appropriate to it are observation, description, and classification. It differs from the next stage of inquiry, where the method of hypothesis enters and deductively formulated scientific theory occurs. In the former concepts are "concepts by intuition, where intuition means, not a speculative hunch, but the immediate apprehension of pure empiricism, which occurs in direct inspection or pure observation."[28]

Most of "factual studies" in economics are not of the "purely empirical" type. For example, Kuznets and Jenks in their voluminous study of capital in the American economy admit that "the study is . . . largely a compound of estimation and classification, seasoned at different levels of empirical findings with conjectural explanation, and topped off with a frosting of impressionistic speculation [?!]. . ."[29]

These authors find economic theory of little help in their factual studies:

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[27] Ibid.,

[28] Ibid.

[29] Simon Kuznets, Capital in the American Economy, Princeton, New Jersey: Princeton University Press, 1961, p. 7.

> With the ordered empirical findings at hand, the next task in logical sequence was that of explanation--of attempting to show with what patterns of established generalizations a specific finding could be associated, of what general law it was a specific case. Since there are few such generalizations or laws in the field of economic knowledge, and since any linking of a given set of findings to some established theoretical tenets require more precise knowledge of the mechanism involved than is available, adequately tested explanations are not now feasible (Emphasis added, M.M.). . . .[30]

This optimism is typical of nontheoretical economists engaged in factual statistical work. Few if any suspect that economic theory may be incapable of coming closer to the empirical reality about which it theorizes. There prevails a faith that the methodology of economics is fundamentally sound, and that the works of economic theorists and economic empiricists are truly contributing to the growth of science. In the meantime the empiricists explain their "findings" with "impressionistic speculation" and the theorists continue their perpetual "model building" each model differing from the other in the omission, modification, or addition of one or more assumptions, and the degree of sophistication in the mathematics involved. Few bother to even raise the question of empirical implementation of their models, leaving this task to econometricians. (More of the role of econometrics will be said later.) The intimate relation between theory and fact is forcefully underscored by Northrop:

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[30] Ibid., pp. 7-8.

> . . . If one proceeds immediately to the deductively formulated type of scientific theory, . . . before one has passed through the natural history type of science with its inductive Baconian method. . . , the result inevitably is immature, half-baked, dogmatic and for the most part worthless theory.[31]
>
> In the case of economic theory Leontief writes that "seldom, in modern positive science, has so elaborate a theoretical structure been erected on so narrow and shallow a factual foundation. Traditionally--and that tradition still prevails among mathematical and non-mathematical economists alike--'pure' theory has not been implemented with empirical determination of any of the numerical parameters involved. . . . All empirical assumptions on which such theories are based are qualitative in character and, at that, they are quite vague and general. So are the few propositions at which pure economic theory arrives.[32]

Thus, economics seems to be divided into two separate compartments: theoretical economics and "speculative-empirical"[33] economics. Actually there exists a third compartment: the data collection agencies of business, government or other agencies. Paradoxically this is perhaps the most relevant of the three even though the individuals participating here are often not known as

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[31] Northrop, pp. 37-38.

[32] Wassily Leontief, "Mathematics in Economics," Essays in Economics: Theories and Theorizing, New York: Oxford University Press, 1966, pp. 33-34.

[33] This term is used to refer to the type of factual study that is not of a purely empirical type but abounds with "impressionistic speculations" as Kuznets puts it. Above, footnote 29.

economists. This relevance to a true science of economics is due to the affinity of the works of these agencies to the Northrop view of the natural history stage of science. The factual materials collected and classified here is less distorted and "explained" than those provided by the speculative empiricists.

The purpose of the next few sections is to study the methodological aspects of induction in more detail. After studying the components of induction, particularly observation and classification, an appraisal of the role of induction in science will be presented.

C. Observation

The relation between sense--that is, immediate perception--and reason is a central question not only in epistomology but also in philosophy of science, for it focuses on problems of the status and validation of scientific knowledge. "All would be much simpler if observation itself were as simple and unambiguous a process as it appears."[34]

But a fundamental difficulty arises because observation is partially dependent upon the knowledge of the observer. In Cohen's words: "We can claim, indeed, that we 'see' the fixed stars, the earth eclipsing the moon, bees gathering nectar for honey, or a

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[34] M. W. Wartofsky, Conceptual Foundation of Scientific Thought, New York: The Macmillan Company, 1968, p. 100.

storm approaching. But we shall be less ready to maintain that we simply and literally _see_ these things, unaided by any theory, if we remember how comparatively recent in human history are these explanations of _what_ it is we see."[35] Thus, unless observation is identified with an immediate, ineffable experience, one is forced to go beyond observation in order to observe!

It is the observation of the "immediately comprehended facts" that is emphasized by the empiricists. But this category of "immediately comprehended facts" is not without its difficulties. Recent research in the physiology and psychology of perception suggest that the perception process is utterly selective in receiving impressions from the environment. Brunner, _et al._ note that: "were we to utilize fully our capacity for registering the differences in things and to respond to each event encountered as unique, we would soon be overwhelmed by the complexity of our environment. . . . Such discrimination capacities . . . if fully used, would make us slaves to the particular. . . ."[36] As Wartofsky elaborates in detail, this selectivity that characterizes perception, this "ordering of experiences" has survival value for the organism. It is a genetically

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[35]M. R. Cohen and E. Nagel, _An Introduction to Logic and Scientific Method_, New York: Harcourt, Brace and Company, 1936, p. 215.

[36]J. S. Bruner, J. J. Goodnow, and G. A. Austin, _A Study of Thinking_, New York: John Wiley and Sons, 1956, Wartofsky, p. 34.

inherited characteristic of organisms.[37]

Thus, ordinary perception of man, like that of all animals, already operates abstractively; that is, it sorts out for attention, recognition, and generalization some, but not all of those features of different situations which may be said to be alike in some respect. The "abstractions" which perception achieves at this level, it may be said, are not yet detached from the actual situations themselves, nor are they represented in some explicit symbol apart from direct responses to environmental stimuli.[38] This may be referred to as perceptual abstraction.

The above discussion may be summarized by saying that human mind is only selectively attentive to its environment. Many phenomena occur which are potentially observable by man but he does not observe them.

Now, observation is a necessary component of scientific work in general. The objects of scientific observation are, in general, not "immediately comprehended facts." The untrained observer, looking at a slide under the microscope may in fact not perceive what to the trained observer is perfectly clear. Morgenstern complains that economic statistics are frequently not gathered

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[37] Ibid., pp. 34-35.

[38] Ibid., p. 35.

by highly trained observers but by personnel collected ad hoc. "Even trained census-takers and many others engaged in field work are not 'observers' in a strict scientific sense. A scientific observer is the astronomer at his telescope, the physicist recording the scatter of mesons . . . , etc.; all are themselves scientists; they do not operate through agents many times removed."[39] Thus, facts are to be sought by "trained observers." The more a science progresses the less obvious and immediate the phenomena to be observed.

The data used in the physical sciences today are only in a small measure directly accessible to senses. Most phenomena are only available through indirect measurement and many have lost all traces of direct, intuitive appeal. They are represented by numbers, relations, equations, etc. Many phenomena can never be seen, heard, felt, except in a crude and most indirect manner.[40]

In economics many phenomena seem to be immediately observable. But a closer examination reveals that this is not the case. Take for instance, money. Is money a thing to be observed? Is money a tangible thing or is it a social relation? Asking the question is sufficient to indicate what elusive a concept this is. It is true that in a

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[39] Oskar Morgenstern, On the Accuracy of Economic Observations, 2nd ed.; Princeton, New Jersey: Princeton University Press, 1963, p. 27.

[40] For a more detailed treatment of this point see Morgenstern, p. 539.

well-defined theoretical system such as, for example, the Walrasian general equilibrium model, the concepts assume a well-defined character. But in its real, objective existence, it is not so directly understood as it is generally thought. How is this phenomenon to be observed and measured?[41]

Or take the concept of capital. What is capital? Is every "produced means of production" to be considered as capital? Is labor to be treated as primary or produced means of production? What is labor? Even a casual survey of the history of economic thought will impress the investigator by the variety of the answers provided by different economists--each plausible and defensible in its own context--to such questions. No wonder that many economists have escaped from the task of observing economic phenomena and have found a safe haven in the world of abstract theory where they assume that the concepts of money, capital, labor, etc., are operationally meaningful and, therefore, theoretically justifiable. The task of observation is left to the accountants and statisticians of the governmental and business agencies. The true challenge in economics is to develop such schemes that would indicate (1) what is to be observed, and (2) how it is to be observed (and measured).

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[41] The controversy among monetary circles on whether to define time deposits as money or "near money" is one instance of the elusiveness of the concept.

The usefulness of an observation is impaired if the conditions under which it is made is not known. The information that a certain liquid boils at 60°C is useless by itself. Only if atmospheric pressure and density of the liquid are also given, can the above information be of any value. This shows how futile it can be to collect data without at the same time describing the relevant features of the reality about which the data are collected. But how is one to distinguish relevant from irrelevant features? Lange gives a clue: "Abstraction consists in the mental elimination of everything which is casual or accidental, i.e., occurring only occasionally, and in singling out the event which constantly under given conditions reappears, which constantly repeats itself, i.e., is essential, or necessary."[42] But this already requires an insight, familiarity, or access to a theory with regard to the process under observation.

This dependence of observation on theory should not be interpreted mechanistically. The process is a complex one. In some branches of science a more or less "natural" avenue of observation has existed; hence, these sciences were not dependent on preconceptions (in the form of hypotheses) in order to select and observe the phenomena of their domain. In others the dependence of observation on theoretical notions is more. Only examination of the concrete

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[42] Lange, Political Economy . . . , p. 103.

historical development of some selected fields can illuminate these differences. Therefore, an outline of the developments of biology and psychology will be presented here in an attempt to give illustrations of the interplay between fact and theory in the evolution of sciences. The problem will then be investigated with reference to economics.

D. Fact- Theory Interdependence

i. Biology Much of biology is historical in nature: it is natural history in the sense that it deals with particular facts about nature that involve time in an essential way. Biological facts, among other things, are temporally related. This temporal dependence among facts is by no means a unique feature of biology. Geology (and paleontology), astronomy, and cosmology are examples of other sciences for which facts are of a natural-historical character. It will be seen that some economic facts can usefully be regarded as natural-historical. Some interesting observations follow from this analogy.

The study of biological natural history is useful because (1) it provides a classical case of the Baconian type of empiricism; (2) it provides a concrete medium for the study of taxonomy[43]--the science of classification of objects; and (3) it gives an opportunity to examine the role of classification in the development of sciences. This is of

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[43]Taxonomy = taxis (arrangement, division) + nomos (a law).

methodological interest in economics.

Systematic categories of plants, animals, and other objects have existed in man's mind even at the most primitive stage of development. The reason for this is illucidated by Nordenskiold as follows:

> As long as man's knowledge of nature is limited to what he can observe in his immediate vicinity, he has little difficulty in controlling the objects of his knowledge. But when his range of vision widens, there arises the irresistable need for combining the individual objects that have been observed under general expressions, which serve to fix the knowledge of them and to impart it to others, since no language would suffice to denote everything individually, and since in a language that did so, no understanding, no common knowledge, nor retention of such an infinity of terms would be possible.[44]

Thus, among primitive peoples natural objects are grouped out of sheer practical necessity. The categories in which objects are grouped are based on such qualities that are easily observed and comprehended, and are of particular importance in relation to food, shelter, defense, or other useful (survival-related) considerations. The same is true, in a modified form, of the civilized people who invent (folk) terms for objects whenever they are concerned with nature in a purely practical way. Thus, many objects have a scientific and a popular name, the two being usually different.

The grouping of natural objects on a scientific principle took a long time. The first known such attempt is due to Plato and Aristotle.

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[44]Erick Nordenskiold, The History of Biology, trans. Leonard Bucknall Eyre, New York: Tudor Publishing Company, 1928, p. 190.

Plato distintuished between genera and species. Species take account of the specific character and genera of the generic character. Aristotle applied his concepts of genos, the family, and eidos, the specie, for classification of animals. A very primitive animal system was left by him, not in a unified collection but scattered throughout his writings.[45] During the centuries that followed there was no need for a more detailed classification; the animals and plants which became known in late antiquity and the Middle Ages were not so numerous that they could not be covered by the Aristotelean system. "It was not until the great geographical discoveries of the sixteenth and seventeenth centuries introduced the knowledge of a great number of new life-forms that it was an inevitable necessity to widen the biological classification if the material collected was not to accumulate into an absolutely intractable mass."[46]

But the early attempts at developing a classificatory system were not very successful. For example, Cesalpino (1519-1603) began his definition of the difference between plants and animals in the true

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[45] Genera, differentia, species, etc., are actually all among the basic components of the Aristotelean theory of science and his system of logic. Thus, for him the application of these concepts to biology was a mere instance of the use of his general system. For a discussion of this point see Cohen and Nagel, pp. 231-238.

[46] Nordenskiold, p. 191.

Aristotelean style: plants feed, grow, and produce offspring, but lack the sensibility and motion of animals and therefore also need smaller organs than animals.[47] Then follows a comparison between vegetable and animal organs, which, "owing to its abstract one-sidedness, leads to curious results: the alimental organs of plants are the roots; thus these correspond to the stomach and intestinal canal in animals. Stalk and stem produce the fruit; thus they belong to the reproductive system. . . ."[48]

The above should clarify one point: the present state of biological and botanical taxonomy is the result of systematic efforts of many generations of scientists over the past four centuries. In the beginning there did not exist a "natural" classification to be simply observed and recorded by taxonomists. The belief often held that these sciences are endowed with such data which can be easily arranged in a "natural" order is utterly unfounded. Indeed a closer examination reveals how vague the notion of "natural classification" is.

During the first two centuries of the modern era plant classification was splendidly reorganized, but animal classification on the whole made no progress. The very first to make an attempt to deal

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[47] Ibid., p. 192.

[48] Ibid.

with vegetable and animal classification on similar principles was Ray (1627-1705); the scientist who finally worked out a uniform system for all living creatures was Carolus Linnaeus (1707-1778).

In the eighteenth century the French naturalists and in the nineteenth century Hegel upheld and popularized a conception of Nature as a whole, "moving in narrow circles and remaining immutable, with its eternal celestial bodies, as Newton taught, and unalterable species of organic beings, as Linnaeus taught."[49] The reaction to this view was inevitable. New findings were continually contradicting such a rigid concept of nature. Kant (1724-1804) resolved the stable solar system of Newton into a historical process: the formation of the sun and of all the planets out of a rotating nebulous mass. He drew the conclusion that given this origin of the solar system, its ultimate dissolution was also inevitable. Half a century later his views were given a mathematical basis by Laplace (1749-1827), and another fifty years later the spectroscope proved the existence in space of such incandescent masses of gas in various stages of condensation.[50] Thus, Linnaeus came to be accused as Aristotelian in a derogatory sense. But this is likely in all ages to be "laid at the door of everyone desirous of arranging things according to formal

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[49] Engles, Herr Eügen Dühring's . . . , p. 31.

[50] Ibid., pp. 29-30.

principles, and that was what Linnaeus desired, just as it was exactly what biology in his time needed. . . . The posterity should be grateful to him for having, instead of working out speculatively some doubtless unproductive system of thought, devoted himself entirely to ascertaining the relation of forms to one another. . . . "[51]

Linnaeus never survived the polemics leveled at him and to this day he remains un-rehabilitated among the historians of science.[52]

The method of Linnaeus consisted in explaining and defining the various parts of the plant and then working out the principles of nomenclature, synonymy, and characteristics of the various categories in his system. His basis for the classification of plants was sexuality among them. The classes are determined according to the number of stamens and the orders according to the number of pistils.[53] The practical utility of this system is evidenced by the fact that it is used to this day in school education, although it was long ago abandoned in actual scientific work.

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[51]Nordenskiold, pp. 207-208.

[52]This author surveyed about 20 different books in the areas of philosophy of science and history of science. Only three of them even mentioned Linnaeus as an important scientific figure. For an interesting explanation for this see Nordenskiold, pp. 215-218.

[53]He distinguished between classes, orders, genera, and species with specie being the most specific and class the most general entity. For elaboration on this see Nordenskiold, p. 210.

In his later writings Linnaeus became increasingly aware of the shortcomings of his method of delimitation of the species. He began to doubt his doctrine of the immutability of species and in the final edition of his Systema Naturae he omitted the definite assertion that no new species arise.

The analysis of Nature into its individual parts, the grouping of the different natural processes and natural objects in definite classes, the study of the internal anatomy of organic bodies in their manifold forms--these were the fundamental conditions of the gigantic strides in knowledge of Nature which have been made during the last five centuries. Mayr notes that "indirectly, Linnaeus did as much to prepare the ground for a theory of evolution as if he had proposed such a theory himself."[54] It is essential to note that this type of "natural history" stage in the development of sciences is not just another aspect of scientific work. It is a necessary, transitional phase in the evolution of the science. As Mayr notes:

> The development of the modern theory [in biology] was a slow process. Evolutionary biology was at first in the same situation as sociology, psychology, and other vast fields still are today: the available data were too voluminous and diversified to be organized at once into a single comprehensive theory. Individual, specialized theories had to spotlight selected aspects and assist in a preliminary sorting of the data before a complete synthetic

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[54] Ernest Mayr, Animal Species and Evolution, Cambridge, Massachusetts: Harvard University Press, 1963, p. 4.

interpretation of the field as a whole was feasible.[55]

Biology had to rescue itself from some philosophical concepts that had been handed down from the antiquity. These were "performism" and "typological thinking." The latter will be discussed because of its relevance to taxonomy in general.[56]

Plato's concept of eidos is the "formal philosophical codification" of the typological conception of nature.[57] According to this conception the vast observed variability of the universe has no more reality than the shadows of an object on a wall. Fixed, unchangeable "ideas" underlying the observed variability are the only things that are permanent and real. Such idealistic[58] modes of thought dominated the natural sciences until well into the nineteenth century. Mayr is worth quoting in full:

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[55] Ibid., p. 3.

[56] Mayr defines "performism" as follows: "Performism is the theory of development that postulates a performed adult individual in miniature 'boxed' into the egg or spermatozoon, ready to 'unfold itself' during development." Ibid., p. 4.

[57] Ibid., p. 5.

[58] Philosophical idealism is a school of thought which "reduces" reality to mental phenomena, denying the objectivity of things and processes in nature. The most articulate members of the school were George Berkeley (1685-1753), G. W. Friedrich Hegel (1770-1831), and the Austrian physicist Ernst Mach (1838-1916). The latter was influential in the development of so-called logico-positivism which has had

> The replacement of typological thinking by population thinking is perhaps the greatest conceptual revolution that has taken place in biology. . . . The assumptions of population thinking are diametrically opposed to those of the typologist. The populationist stresses the uniqueness of everything in the organic world. . . . All organisms and organic phenomena are composed of unique features and can be described collectively only in statistical terms. Individuals, or any kind of organic entities, form populations of which we can determine the arithmetic mean and variation. Averages are merely statistical abstractions; only the individuals of which the populations are composed have reality. . . . For the typologist, the type (eidos) is real and the variation an illusion, while for populationist the type (average) is an abstraction and only the variation is real. . . .[59]

The above reflects the sharpness of the conflict between two modes of thought in biology: subjectivism versus objectivism. The battle had to be won in favor of objectivism as biology developed into a mature science. This battle is yet to begin among economists.[60]

With regard to the importance of this problem Mayr notes that it was Linnaeus' insistence on the "constancy and objectivity" of species that posed the problem of the origin of species, a problem previously

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an important impact upon the methodology of social sciences. Wiener, pp. 462-470, 480-484.

[59]Mayr, p. 4.

[60]The author is aware of the methodological polemics between the historicist school and other schools of economic thought. Also the works of W. C. Mitchell in data collection and economic empiricism is not ignored. But it will be argued later in this chapter that objectivism in economics has, until recently, been understood in a one-sided and incomplete sense.

nonexistent in that form. The whole concept of evolution would be meaningless if species were the "arbitrary and ephemeral" units of the pre-Linnaean period.[61]

Mayr remarks that a new conceptual danger to the evolutionary theory comes not from metaphysics--in the form of "typologicalism" or "performism"--but from physics.[62] Some physicists who believe in reductionism[63] have attempted to express the laws of evolution in terms of the laws of physics. It is alleged that evolution is one more expression of the general principle of irreversibility embodied in the second law of thermodynamics. Such "facile analogies have no operational value. To drag the second law of thermodynamics into the discussion of evolutionary irreversibility confuses two distant levels of integration, the atomic level and the level of the phenotype."[64] Mayr concludes that this view comes "dangerously close to performism."[65]

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[61] Mayr, p. 13.

[62] Ibid.

[63] Reduction is a philosophical view, gaining popularity in recent times, which holds that laws of a science (e.g., biology) can be "reduced" to more fundamental laws such as those in chemistry and physics. See H. Feigl, M. Seriven, and G. Maxwell, Minnesota Studies in the Philosophy of Science. Vol. II: Concepts, Theories, and Mind-Body Problems, Minneapolis: University of Minnesota Press, 1963, 122-130.

[64] Mayr, p. 13.

[65] Ibid.

As a final note it may be pointed out that the classificatory schemes in biology, having started from purely observable characteristics of organisms, has increasingly shifted to a theoretical basis. The morphological species concept, which dominated animal taxonomy during the nineteenth and early twentieth centuries, is steadily losing ground. The primary criterion of species rank of a natural population is "reproductive isolation."[66] The degree of morphological difference is a by-product of the genetic discontinuity resulting from reproductive isolation. Hence, as an outgrowth of the theory of evolution, the morphological basis of classification came to be replaced by one more deeply imbedded in theory, namely a phylogenetic basis.

ii. Psychology. Both psychology and psychiatry have been preoccupied with attempts towards the development of a classificatory scheme over the past century. Zilboorg[67] and Menninger[68] have reviewed the history of psychiatry, "which in many ways can be said to be a history of attempts to classify psychological disorders."[69]

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[66] Two organisms that are unable to interbreed are called "reproductively isolated."

[67] G. Zilboorg and G. W. Henry, A History of Medical Psychology, New York: W. W. Norton, 1941.

[68] K. A. Menninger, The Vital Balance, New York: Viking, 1963.

[69] L. L. Robins, "A Historical Review of Classification of

Zilboorg states that:

> The question of the causes of mental diseases plagued the curious observer; even if he were inclined to substitute speculation for knowledge, he still was curious enough to remain unsatisfied and to hope for a reasonably specific and substantial answer to his query. A classification became therefore a partial proclamation of one's views on the causes of various mental diseases. . . . The nineteenth century was the golden age of descriptive psychiatry, for at no previous time had the psychiatrist at his disposal such a great number and variety of mental diseases. To bring some order into the mass of facts observed there was naturally the need to classify the data.[70]

Thus, psychology, like any other science, starts with observed phenomena and attempts to develop a set of propositions, a theory, that would bring "some order into the mass of facts observed." A study of the classificatory work in this field is therefore of interest, because this is merely a specific instance of a general scientific activity. This provides an opportunity to, so to speak, watch the scientist at work, and to see the problems he faces in specific terms. This is a method of studying the general problem of classification _in concreto_.

But there is another, perhaps more important, reason for selecting psychology as a concrete medium of the study of the classification problem. This has to do with the nature of the "observed"

Behavior Disorders and One Current Perspective," _The Classification of Behavior Disorders_, Leonard D. Eron, Chicago: _Aldine Publishing Company_, 1966, p. 8.

[70] Zilboorg, p. 420, as quoted in Robins, _ibid._, pp. 8-9.

phenomena in psychology. It is the question of the objectivity of such observations and the degree of their dependence on theoretical preconceptions that makes the field particularly interesting for methodological comparisons with economics. This point will be elaborated upon in some detail.

A third feature of interest, with an interesting parallel in economics, is related to the general acceptance of the Freudian theoretical system, or modifications thereof, by the various schools in psychology. It is the resemblance--in a methodological sense--of the Freudian system with the prevailing system in economic theory that is of interest here. Both systems are characterized by a giant theoretical superstructure built on a narrow base of empirical observations.[71] The above propositions will be elaborated upon in the following sections.

a. Freudian observations. To be sure the Freudian influence among psychologists is less today than a decade or two ago. However the general acceptability of Freudianism (or lack of it) is not

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[71]Freud started with two observations: (1) that his patients had forgotten many facts of their lives; (2) events that had been forgotten had in some way or other been painful. Freud proceeded to build a giant superstructure of assumptions to account for these two observations: sexual (libido) and death instinct, cathexis or psychic energy, censorship or anti-cathexis after repression, and circuitous routes and disguises by means of which repressed impulses gain entrance to consciousness; see Harry K. Wells, Sigmund Freud: A Pavlovian Critique, New York: International Publishers, 1960, pp. 53-66.

necessary for the purpose of the discussion in this chapter. The method of Freud is interesting and has some parallels in economics. That is why it is studied here in some detail.

"The doctrine of repression," Freud wrote, "is the outcome of psychoanalytic work, a theoretic inference legitimately drawn from innumerable observations."[72] These observations were made by means of dream interpretation with the aid of free association and the meaning of symbols. The "innumerable observations" related to the following three phenomena: (1) dream analysis and free association revealed that the patient had forgotten many facts of his past life; (2) everything that had been forgotten had in some way or other been painful--either alarming or disagreeable or shameful by the standards of the subject's personality; (3) to bring the patient to remember the forgotten facts of his life it was necessary to overcome something that fought against their recall--it was necessary for the analyst to make an expenditure of effort to compel and subdue it.[73]

Now, in the case of any specific patient the facts to be observed are the contents of his long-forgotten experiences, thoughts, or impulses. But these are not readily available and must, therefore, be

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[72] Sigmund Freud, New Introductory Lectures on Psychoanalysis, New York: John Wiley and Sons, 1933, p. 131, as quoted in Wells, ibid., p. 53.

[73] For a detailed account of these see Wells, pp. 53-99.

detected by the analyst. As aids in this process of detection of forgotten materials or unconscious memories, Freud relied on such observable phenomena as symptomatic actions, for example fingering objects or tapping with fingers during the analysis. Slips of tongue and pen, errors involving forgetting of whatever kind, and developing attitude on the part of the subject directed toward the analyst were to be closely observed. By means of all these indications, but primarily by means of the interpretation of dreams, Freud sought to discover the unconscious forgotten material stored in the lower depths of the mind.[74]

The observational task of the analyst is twofold; to identify the disguised forms and to penetrate through the disguise to uncover the originally repressed and long-forgotten impulse. The disguised forms are symptomatic and impulsive changes in the motor activity of behavior. Behind such symptoms lies the repression of some biological instinct sometime during the patient's life. Disguises are means by which repressed instinctual impulses gain entrance to consciousness.[75]

As to the nature of instincts and Freud's choice of distinction and classification of them, he asks: "Now what instincts and how many should be postulated?"[76] (Emphasis added, M. M.) If only other

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[74] *Ibid.*, p. 54.

[75] *Ibid.*, pp. 56, 66.

[76] *Ibid.*, p. 71.

sciences such as physiology and biology had successfully investigated the problem, it would not be necessary for psychology to make arbitrary assumptions. Since there was no such knowledge available then, no real objection could be raised against anyone's choice. "When there is no verified knowledge, there is ample room for arbitrary choice."[77] Thus, Freud proceeds with his theory building on speculative grounds: "On the basis of speculation concerning the origin of life. . . , I drew the conclusion that," besides the erotic instinct, "there must exist another in antithesis to this," the death instinct.[78] "We suppose," he says, "that there are two fundamentally different kinds of instincts. . . ."[79]

This speculative approach was by no means a matter of free choice but dictated to Freud by the contemporary gap in the physiology of human brain and in cerebral knowledge in general. Lacking such knowledge, Freud resorted, of necessity, to construct his "Metapsychology" (Freud's term), namely, psychological speculation, the psychological counterpart of metaphysics. "The latter has always

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[77] Ibid.

[78] Sigmund Freud, Civilization and Its Discontent, pp. 97-98, as quoted in Wells, p. 72.

[79] Freud, New Introductory Lectures . . . , p. 147, as quoted in Wells, p. 72.

been, historically, in any field a substitute for scientific knowledge.'[80]

Some exponents of Freud argue that psychoanalysis is without question founded on observation of patients. The basic working theories of the unconscious, repression, sublimation, regression, fixation and the like are said to be the outcome of practical experience and to be thus independent and separable from Freud's metapsychology, that is, his overall theoretical structure. The claim is made that Freud the psychoanalyst founded a science of unconscious mental life based on his work with his patients. But Wells has examined many of these "component theories" and concludes that they explicitly rely on the metapsychological assumptions.[81] Wells notes that the "very 'observations' themselves were determined by the concept of the hereditary mental apparatus, especially by the assumption of an innate archaic language of the unconscious in the form of stereotyped symbols biologically inherited by man."[82]

Wells proceeds to state that:

> The fact that Freud's 'observation' of dreams and the like are seen through the colored glass of inborn sexual symbolism, transforms these 'observations' into interpretations. In his theory of repression, of dreams, of

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[80] Wells, p. 81.

[81] Ibid., p. 221.

[82] Ibid., pp. 221-222.

> character formation and of the etiology of the neuroses, the 'observations' have already passed through a dye process indelibly imbuing them with speculative, mythical hues. If this is true of the observations, the raw material of the theories, it is all the more true of the theories themselves.[83]

Thus the contention that the speculative part of Freudian system can be discarded while saving the pure alloy of his observations is utterly unfounded. Freud's metapsychology is the _sine qua non_ of all his observations.[84]

Methodologically Wells lists eleven characteristics of the Freudian system, three of which are of interest to this discussion:

First, Freud's general approach is purely mental. Paying lip service to the established fact that mind is a function of the brain, he proceeds as if the human psyche were an independent, disembodied phenomenon. "Technically, this approach is called _dualistic idealism_ in the psychological form of psychophysical parallelism."[85]

Second, his conceptual material is in large part drawn from the by-ways of human intellectual history. He explicitly reserved the right to select those ideas and theories which suited his purpose or need: "Technically, this should be termed _expedient eclecticism._"

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[83] _Ibid._, p. 222.

[84] _Ibid._, p. 224.

[85] _Ibid._

Third, his method of observation is primarily symbol-translation of the imagery of dreams, fantasies, slips-of-tongue and pen, symptomatic actions, unconscious associations and neurotic symptoms. By this "empirical"method, in the first place practiced on himself, he collected the "observational material" out of which his theories were constructed. "Technically, this method should be called <u>esoteric introspection</u>."[86]

In contrast to Freud, Pavlov conceived of the basis of human mental activity in terms of the cerebral hemispheres and their functioning. He held that psychology and psychiatry could not develop much further as <u>sciences</u> until the physiology of higher nervous activity had laid a firm foundation on which they could be built.

Pavlov initiated the work in this direction and developed his theory of conditioned reflex entirely as generalizations from experimentally derived facts. These generalizations were then tested and revised in the course of innumerable further experiments, leading eventually to verified, and verifiable, laws and theoretical conclusions.[87]

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[86] <u>Ibid.</u>, pp. 224-225.

[87] An excellent introduction for a general-purpose reader to Pavlov's work is Harry K. Wells, <u>Pavlov: Towards a Scientific Psychology and Psychiatry</u>, New York: International Publishers, 1956. For a contrast of Pavlov and Freud see Wells, <u>Sigmund Freud . . . .</u>

Wells concludes that even the Pavlovian approach does not provide a sufficient basis for the development of the sciences of psychiatry and psychology. Scientific psychology should not limit itself to a knowledge of cerebral physiology. Since environment is such an essential factor in the determination of human psychic qualities, a scientific knowledge of society is indispensible. Thus, social sciences and their development are necessary preconditions for further advances in psychology. On the other hand the understanding of cerebral physiology is dependent on developments in biophysics and biochemistry of human nervous system. In all cases a scientific epistomology is required to continually remind the investigator of the necessity of avoiding speculative assumptions, and to insist on objective (as opposed to introspective) observation to be classified and interpreted by well-established methods of scientific generalization. However, in certain cases introspection may prove useful as a guide to hypothesis formulation. But at all times independent, objective tests are the ultimate factor towards establishing the truth of a given proposition.

A different point of view, heavily based on observation of various animals is emerging, tracing human behavior to its embryonic forms among animals.[88] This approach alleges that it rests on

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[88] A very fascinating introduction to these works may be found in William Etkin, Social Behavior from Fish to Man, Chicago:

biological and ecological grounds and that it is essentially the application of Darwinian theory of evolution to the problem of "sociality" among animals and man.[89] In spite of the plausibility of many conclusions of this approach it suffers from a number of serious methodological weaknesses.[90] A close examination of Eiken's "ethological concept of instinct" reveals the speculative nature of his approach.[91] Elaboration on this point is hardly justifiable here.

The above schematic study of the nature of Freudian observations point to the unescapable conclusion that Baconian empiricism, relying on so-called "pure observations" can be seriously misleading if it is not attended by the critical spirit of scientific objectivity. In fact, it was precisely the tradition of the British empiricism that degenerated into the "science of spiritualism" (?!) in the latter part of the nineteenth century. For example, the very eminent zoologist and botanist, Alfred Russel Wallace, the man who simultaneously with Darwin put forward the theory of the evolution of species by natural selection, published in 1875 his "spiritual studies": <u>On Miracles and</u>

Pheonix Books, The University of Chicago Press, 1967.

[89] <u>Ibid.</u>, p. 4.

[90] Unfortunately even a schematic examination of this approach would demand a lengthy digression which is not deemed justified due to scope considerations.

[91] Etkin, pp. 78-84.

Modern Spiritualism. A second eminent scientist who joined the rank of spiritualists was William Crookes, the discoverer of the chemical element thallium and the radiometer. He began his spiritual work in 1871 and, faithful to the tradition of empiricism, employed for this purpose a number of physical and mechanical appliances, spring balances, electric batteries, etc. This Mr. Crookes "succeeded" in scientifically determining how much weight is lost by tables and other articles of furniture in the presence of spirits!! Similarly Mr. Wallace declared it scientifically proven that fire does no harm to the human body in the world of spirits.[92]

It can be said, therefore, that observation is an intricate part of scientific inquiry, that it is an integral part of the whole process of inquiry, that taken by itself and in separation from theoretical knowledge it can lead to absurd results,[93] and that it cannot be suppressed and done away with in the interest of theory. Theory and observation are the two inseparable parts of any scientific activity. It is the dynamic interdependence of the two that leads the process of inquiry to the discovery of laws of nature. Any discipline that departs from this fundamental methodological axiom is bound to be

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[92] For references to works of Wallace and Crookes see F. Engles, Dialectics of Nature, trans. Clemens Dutt, New York: International Publishers, 1940, Chapter X.

[93] It should be noted that much of superstition, religious or otherwise, in primitive societies, were the result of direct observation!

frustrated in actual application. Economics is in such a state *par excellence.*[94]

b. Classification in psychology. The preceding section dealt with two aspects of the process of observation in psychology: the narrow empirical base of some psychological theoretic systems; and the predetermined nature of the empirical observations in the sense that they depend on theoretical preconceptions.

In this section the problem of classification of psychological observations will be studied.

Prior to the development of psychological theories, all psychiatric diagnoses were based on the practical knowledge of the physicians. It was frequently possible to predict "what will be" from "what is" even though it was not (and still is not) possible to state why. The essence of present psychiatric diagnosis is to utilize descriptive concatenations that have corollaries in the past, present, and future. It is based upon the awareness that the coexistence of various clinical phenomena is not merely coincidental, but that there are some antecedent factors that have led to their appearance, and that there exists a "usual" future course.[95]

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[94]This allegation will be substantiated in the following sections.

[95]Robins, pp. 7-8.

Throughout most of the nineteenth century all efforts at classification were based primarily on the symptoms of mental conditions, and little light was shed on etiology. Various new classifications added to the vastness of psychiatric terminology, but they were short lived. As long as there was nc unitary principle for classifications there could be nothing but terminological attempts at improvement.[96]

The classificatory ambition was so conspicuous during this period that the composer Hector Berlioz "was prompted to remark that after their studies have been completed a rhetorician writes a tragedy and psychiatrist a classification."[97]

As for the present classification systems, Robins notes that a review of these "demonstrates the need for major effort to achieve some degree of uniformity in our nomenclature by at least agreeing on operational definitions for certain types of abnormal behavior rather than attempting to achieve agreement in regard to hypothetical illnesses."[98]

Robins refers to Stengel's criteria for usefulness of scientific concepts in classificatory works:

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[96] Ibid., p. 11.

[97] Zilboorg, p. 450, as quoted by Robins in Eron, p. 12.

[98] Robins, ibid., p. 16.

> A good taxonomic system is based on, and reflects, a more or less comprehensive system of laws. . . . These systems will change with the theoretical advances made in the field. Systems of classes defined in terms of manifest observable characteristics give way to systems whose defining principles are couched in terms of theoretical concepts.[99]

A useful notion has been introduced by Hempel: the "systematic import" of a concept.[100] To illucidate this notion Hempel remarks that to be scientifically useful a concept must lend itself to the formulation of general laws or theoretical principles which reflect uniformities in the subject matter under study, and which thus provide a basis for explanation, prediction, and generally scientific understanding. This aspect of a set of scientific concepts will be called its systematic import, for it represents the contribution the concepts make to the systematization of knowledge in the given field by means of law and theories."[101]

In relation to classificatory work Hempel finds the notion of systematic import useful. He notes that the "familiar vague distinction between 'natural' and 'artificial' classifications" has to do with

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[99] E. Stengel, "Classification of Mental Disorders," Bulletin of World Health Organization, XXI, 1959, 612, as quoted by Robins in Eron, ibid.

[100] Carl G. Hempel, Aspects of Scientific Explanation and Other Essays in the Philosophy of Science, New York: The Free Press, 1965, p. 146.

[101] Ibid.

whether or not the given system of classification is scientifically useful.[102] In a "natural" classification those characteristics of the elements which serve as a criteria of membership in a given class are associated with more or less extensive clusters of other characteristics. For example, the two sets of primary sex characteristics which determine the division of humans into male and female are each associated with a large variety of concomitant physical, physiological, and psychological traits. "It is understandable that a classification of this sort should be viewed as somehow having objective existence in nature. . . in contradistinction to 'artificial' classifications, in which the defining characteristics have few explanatory or predictive connections with other traits; as is the case, for example, in the division of humans into those weighing less than one hundred pounds, and all others."[103]

As Hempel has indicated this principle has its parallels in chemistry and biology. The elements potassium, sodium, caesium, rubidium, and lithium, which are grouped together as forming the class of alkalai metals, have many characteristics in common: they

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[102] Ibid.

[103] Hempel clarifies his position by adding further that the above distinction or other such artificial distinctions are not necessarily useless for certain specific purposes. However, in such cases "the systematic import of the system would seem to be quite small." Ibid., p. 147.

all combine energetically with oxygen, decompose in water at various temperatures, and form strongly basic oxides that are highly soluble in water; their carbonates are soluble in water, and so forth.

Perhaps the most striking example of a classification reflecting a general law is the periodic system of the elements discovered by Mendeleev. On the basis of this table Mendeleev predicted the specific characteristics of some elements which were not known then. The confirmation of these predictions by later research was quite impressive. Further advances in physics and chemistry provided a deeper theoretical foundation for the system, showing that it reflects, in the classes represented by the columns of the periodic table, certain similarities and differences in the atomic structure of the elements.

In the case of biology, as it was noted earlier, there has occurred a shift from a morphological basis of classification to a phylogenetic one, the latter providing a deeper theoretical root with a large number of functional-physiological characteristics being associated with each class.

Having derived the notion of "systematic import" of a set of concepts correctly on the basis of his study of classification in chemistry and biology, Hempel jumps to some very doubtful conclusions about the application of his principle to the classification of mental disorders. In this connection he writes that:

> The concepts determining the various classes or categories distinguished now are no longer defined just in terms of symptoms, but rather in terms of the key concepts of theories [sic!] which are intended to explain [sic!] the observable behavior, including the symptoms in question.[104]

Hempel gives a general reference to the characterization of the various categories of psychoneurotic disorders, as described in the Diagnostic and Statistical Manual,[105] in order to substantiate his remarks.[106] Hempel fails to note that there can be useless theories as well as useful ones, and that it is precisely the irrelevance of the prevailing psychological theories that have made a meaningful classification of mental disorders a speculative exercise in "system building," and a scholastic meticulosity in nomenclature, not a scientific endeavor in taxonomy. What other reason could explain Robins's confession that "the twentieth century finds us, in a way, not much closer to an adequate system for classifying mental disorders."[107]

Hempel does not even suspect that the "theories" he is referring to may be fundamentally irrelevant, subjective, and speculative.

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[104] Ibid.

[105] American Psychiatric Association, Diagnostic and Statistical Manual: Mental Disorders, Washington, D. C., 1952.

[106] Hempel, p. 149.

[107] Robins, p. 16.

In fact, it is precisely in the application of theory to the real phenomena and its failure to find uniformities in the various mental diseases, that its barren nature completely reveals itself. In fact, the more "theoretical" the work on classification of mental disorders has become, the more chaos and confusion inflicted upon the practitioners in the field. With the advent of the fantastic Freudianism the difficulties have increased manyfold. It is difficult to find explicit references to this problem in the literature. This is only natural because an attack on Freudianism is a taboo in the psychiatric and psychological profession. But one can read between the lines: "From psychoanalysis," writes Robins, "we have learned much about the continuum between mental health and mental illness. . . . In a way our task has become somewhat more difficult, for it is harder and harder to draw lines between mental health and mental disease, or between one form of mental disfunction and another."[108] Now, this gives the impression that Freud helped illucidate the essential continuity in mental phenomena just as advances in biological theories eliminated some of the rigidities of the Linnaeus classification of plants. This is not the case. In biology further advances in theory provided a more deep-seated foundation for the Linnaeus system, leaving much of the original classification intact. Theoretical

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[108] Ibid., pp. 21-22.

advances, further, opened room for massive amounts of facts that were continually becoming available. It is different with psychology. Here, the pre-Freudian set-up lacked any theoretical foundation and its empirical usefulness was minimal. The introduction of Freudianism not only did not improve upon the existing classifications, but it essentially did away with them. If this conclusion is difficult to read in the above quotation, then the following should make the point clear beyond any doubt:

"Despite the importance of the contributions of psychoanalysis to our understanding of important and undoubtedly essential aspects of mental illnesses," writes Robins, "we are still not much better off in our efforts to classify the phenomena with which we are concerned. It is not certain whether they can all be ordered along some continuum or whether some must be considered separately from others; and so our quest for knowledge regarding their fundamental etiology continues."[109] This lack of contribution of psychoanalysis to the discovery of some order among psychological phenomena is the surest sign of its essential sterility.

But this is not all. Robins continues: "The psychodynamic approaches can legitimately lead to the conclusions that there is but one mental illness with infinite variations, that there are as many

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[109] Ibid., pp. 27-28.

illnesses as there are people, or that there is no such thing as mental illness, just people."[110] It is here that the ephemeral, elusive, and arbitrary nature of the theoretical concepts of Freudianism are most clearly demonstrated. One is tempted to borrow the term "malleability" from Meade[111] and apply it to the "science" of mental disorders. Meade defines a "perfectly malleable" capital stock as one that can change its concrete nature instantaneously. For example, a tractor can instantaneously be transformed into an automobile and a truck. Thus, a "perfectly malleable" human being is one who can instantaneously be transformed from a "schizophrenic" into a "manic depressive" or into a "normal" individual. This sort of absurd result is the unescapable fate of any theory that bases itself not on observed phenomena of nature but on some subjective presuppositions in the head of the theorist. Psychology was selected for the study of this methodological problem because it, among several "sciences" with similar methodological problems, manifests the problem in its purest form.

Some psychologists have, in recent years, become aware of this methodological problem in their discipline. For example, Eisenberg attacks the view that there is only one mental illness with

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[110] Ibid.

[111] J. E. Meade, A Neo-Classical Theory of Economic Growth, London: Oxford University Press, 1962, chap. 1.

infinite variations--the view that he calls the "doctrine of continuity."[112] He holds that this doctrine presupposes the existence of a spectrum on some single dimension--usually severity of dysfunction--that extends from complete health at one end to severe illness at the other. It is supposed that all points on this continuum are occupied, or are at least potentially occupiable. By this view, disease names become labels assigned to regions of the spectrum more or less arbitrarily. The phenomena observed in the sick would be recognizable in lesser degree in the healthy. This doctrine suggests that a given method of prevention or of treatment would have equal applicability to all of the symptomatic disorders.[113]

But the "doctrine of discontinuity" presupposes qualitative transitions between states of health and states of disease. Such transitions may be the result of factors not present in the healthy or of factors which, though present in the healthy, have "attained super-threshold levels."[114] Accordingly, disease states could not be ordered meaningfully on the basis of a single dimension, but would differ from one another as fundamentally as they differ from health.

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[112] Leon Eisenberg, "The Classification of Psychotic Disorders in Childhood," Eron, p. 89.

[113] *Ibid.*, pp. 89-90.

[114] *Ibid.*, p. 90.

"As I read medical history," writes Eisenberg, "advances in our knowledge of etiology and of treatment have been guided by hypotheses of discontinuity."[115]

Eisenberg makes an interesting observation with regard to medical history which is of methodological significance in all science. He notes that no longer are there treatises "on fever," a heterogeneous aggregate, but rather treatises on specific infections; no longer are there treatments for "lung disease" but rather "theraputic methods for bronchogenic carcinoma, for atypical pneumonia caused pleuropneumonia-like organisms, and so on; no longer does the physician search for the cause of 'feeble-mindedness' but rather the cause . . . mongolism, cretinism, and so on."[116] What begins as a vague category, grouping together a heterogeneous collection of disorders, is gradually broken down. Effective prevention and treatment is based upon the development of methods directed at particular diseases, not "disease" in general.[117] Thus, it is only through a disaggregated and specific approach that the nature of phenomena is revealed.

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[115] _Ibid._

[116] _Ibid._

[117] _Ibid._

iii. Accounting and economics. In accounting there has developed recently an interest in a formal study of data classification.[118] "Classification or division permeates the [accounting] procedure at each stage."[119] In fact, the American Institute of Public Accountants defines accounting as follows:

"Accounting is the art of recording, classifying and summarizing, in a significant manner and in terms of money, transactions and events which are, in part at least, of a financial character, and interpreting the results thereof."[120]

Fitzgerald and Schumer note that the whole process of "recording, classifying, and summarizing is a process of classification in several stages. The usefulness of the data depends on the classificatory schemes used. The way, or ways, in which accounting information may conveniently be analyzed, interpreted and presented depend upon the way, or ways, in which the information has been

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[118] For a review of the literature in this area see A. A. Fitzgerald and L. A. Schumer, Classification in Accounting, Sydney, Australia: Butterworth's, 1962, p. 13.

[119] Ibid., p. 22.

[120] American Institute of Public Accounts, Research Bulletin No. 9, 1941.

classified in evidence records, journals, ledgers, and working papers."[121]

Classification may also be an important aid to development and clarification of accounting theory. Many of the controversies in accounting theory usually turn on questions of consistency of treatment of different classes of accounting data.[122]

As the modern producing unit has changed historically from small owner-manager type of enterprise to large corporations, the accounting process has become increasingly more complex and is more in need of a theoretical basis for classification of accounting data. The recent trend in the rise of the so-called "conglomerates" is bound to amplify this process even more.

The increasing size of business unit and intra-corporation complexities have another impact in relation to the role of theory in conducting business. The rise of Operations Research (or management science) which attempts to solve the decision-making problems of corporations by a systematic application of the "scientific method"[123] reflects a shift from the trial and error approach of the

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[121] Fitzgerald and Schumer, p. 13.

[122] *Ibid.*, p. 23.

[123] See C. W. Churchman, R. L. Ackoff, and E. L. Arnoff, *Introduction to Operations Research,* New York: John Wiley and Sons, Inc., 1957, Chapter I.

owner-manager type--based on the intuition and knowledge of the manager about the overall operation of the firm--to the empirico-analytical approach of the modern corporate unit with its high degree of dependence upon the development of "models" which reflect various aspects of the operation, aiming at understanding and controlling of the process or processes under investigation.

As Operations Research becomes more widespread it is likely that many of the traditional approaches to accounting would be improved, modified, expanded or done away with, and at the same time new frameworks will be developed.

Accounting practices, however, are not the only area that is expected to undergo a significant change. Perhaps the challenge to economic theory is even greater. As a team of Operations Researchers, well equipped with the powerful methodology of physical sciences, persistently studies the intra-corporation economic problems, either they will find the existing economic theory useful or else they will develop their own schemes. The results so far do not indicate much sympathy with economic theory. It is true that many areas of Operations Research--for example, inventory models, replacement models, and break-even analysis--utilize the marginal approach in finding the optimal values of the choice variables under study. But this differs from the approach of economic theory which assumes an overall production function for the firm and relies heavily on the concepts of marginal cost and marginal revenue. In fact, the area that has proved most useful in the analysis and quantification of the intra-corporation economic problems is mathematical programming: linear, nonlinear, integer, dynamic, and stochastic programming. But these techniques are radically different from the Marshallian marginalist approach that has dominated microeconomics since the last quarter of the nineteenth century. Mathematical programming finds little use for the concept of an aggregate production function with its land-labor-capital trinity. It finds the concept illusive and lacking operational significance. The marginal approach with its assumption of smooth substitutability of resources has also proved fruitless in mathematical programming. Instead, it has turned out that a highly disaggregated model of the firm which distinguishes between many different "activities," each activity characterized by one and only one output but a vector of inputs, is most useful in reflecting the complex network of intra-corporation interdependencies.

That economic theory will be radically transformed as a result of this development is already evident in the pioneering works of some economists who are anxious to absorb this new material into the general body of economic theory.[124]

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[124]See, for example, R. Dorfman, P. A. Samuelson, and Robert M. Solow, Linear Programming and Economic Analysis, New York: McGraw-Hill Book Co., Inc., 1958; K. Boulding and W. Spivey,

Mathematical programming is characteristically dependent on vast amounts of data, generally in the form that is not automatically provided by the traditional accounting practices of the firm. This amount and type of data can become available only through conscious effort of the investigator developing the model. Thus, for the first time in history there is occurring in economics--at the firm level--a development that has for long been a feature of natural sciences. That is, the data is actually sought and methods, measurement and organization of facts are actually proposed and closely supervised by the analyst of the given economic problem. This stands in sharp contrast to the traditional case, where the data used by economists is generally those that are made available by various statistical agencies of government or the private sector.

Thus, there is developing a close connection between the theoretical and accounting work with respect to intra-corporation economics. It is ironic that in this respect economics takes a giant step back to some five centuries ago where the pamphleteers on commerce combined their rudimentary economic arguments with their "commercial arithmetic."[125]

Linear Programming and the Theory of the Firm, New York, 1960; R. K. Davidson, V. Smith, and J. Wiley, Economics, an Analytical Approach, Homewood, Illinois, 1958; and R. Dorfman, The Price System, Englewood Cliffs, New Jersey, 1964.

[125]Schumpeter, pp. 156-157

The role of "commercial arithmetic" and its interdependence with the rise of economic categories and hence economic theory has, unfortunately, interested historians of economic thought to a degree not commensurate with its significance. Schumpeter, for example, excludes the literature in this field from his survey "although little pieces of purely economic analysis do occur in them."[126] Yet the development of double-entry bookkeeping was an integral part of and a necessary development along with the transition to a market economy. Lange notes that the development of commodity and monetary relations by singling out and making gainful activity general and by turning it into a rational activity based on reasoning, lead to the quantification and measurability of the end and means of this activity. A quantification of ends and means occurred in terms of uniform units of measurement in monetary units. It became then possible to compare the end achieved (e. g., revenue) and the means used (cost) and to express the result of this comparison in monetary units, leading to the economic category of profit.[127]

"Calculation," writes Lange, "is the expression of fully developed rationality in the activity of an enterprise, since it consists

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[126] Ibid., p. 156; among the members of the German Historical School, however, there was a recognition of the importance of this development. For reference see the following several footnotes.

[127] Lange, Political Economy . . . , pp. 160-61.

in the quantitative comparison of all the constituents of income and cost, together with changes in the value of the property (capital), thus employing logical and mathematical inference. . . . By the use of calculation the means employed by an enterprise are evaluated from the point of view of their profitability. The material technique of production and distribution, like all other operations, is strictly subordinate to the unique end of the enterprise--profit."[128]

Sombart was one of the first economists who drew attention to the development of bookkeeping and its significance as a factor in the rationalization of economic activity. Indeed, he went farther to point to the indirect influence which rationalization of economic activity, in the form of calculation,[129] exerted on the development of the natural sciences. He wrote that:

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[128] Ibid., p. 163.

[129] Lange provides the following useful synopsis of the historical development of economic calculation: The beginning of systematic commercial bookkeeping are to be found in the thirteenth century. Merchants in Italian cities, especially Florence, began to keep systematic accounts of their more important commercial operations. In the fourteenth century accounting is to be found in France as well. Double-entry bookkeeping appeared at the end of the fourteenth century in northern Italian cities. From there it spread to all the major trading centers in Western Europe and especially Holland. The first systematic exposition of double-entry method appeared in 1494 [see Lange for specific reference]. An important part was also played by decimal notation and the method of calculation connected with it, which was taken from the Arabs, having first appeared in India. The transition to the decimal system (early part of thirteenth century) is closely

> Double-entry bookkeeping is based on the consistent application of a conception which treats all phenomena as quantities--quantification, an idea which has brought to light all the marvels of nature and which here, for the first time in history, had become quite clearly the basic idea of a particular system. It requires no great mental effort to see in double-entry bookkeeping the germ of ideas of gravitation, the circulation of the blood, the conservation of energy and other ideas which have proved so fruitful in natural sciences.[130]

Further on, discussion balance accounts, he writes: "This [double-entry] approach determined the creation of the concept of capital. One can also say that before [it] . . . the category of capital did not exist."[131] Sombart also points out that the categories of fixed and circulating capital, the categories of changes in the form of capital, of commercial turnover, capital turnover, production costs, and other categories of political economy arose out of the practical activities of business enterprises.[132]

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connected with the development of accounting and commercial bookkeeping. In northern Italian cities, and later in other countries as well, special schools were set up to train youths in accounting and bookkeeping in order to prepare them to be merchants. Capital accounting appeared later in the sixteenth century. It is worth noting that in Italian the term "regione" was adopted to denote an enterprise and in French the term "raison" (both come from the Latin "ratio"), which originally meant both "reason" and "calculation." Thus the rationality of capitalist enterprise and its connection with commercial calculation shows itself even in etymology; Ibid., p. 162.

[130] W. Sombart, Der Moderne Kapitalismus, 3rd ed.; Munich and Leipzig: 1919, II, 119, as quoted in Lange, ibid., p. 163.

[131] Ibid., p. 120.

[132] Ibid.

Now in the twentieth century once again the practical activity of enterprises is leading to emergence of new theoretical concepts and even complete conceptual structures that may stop at nothing less than a total transformation of the prevailing conceptual frames in economics. It does not appear that the economic profession is fully aware of the implications of this trend, still treating it as another branching off of the existing system--a natural and expectable occurrence in the development of the science. But one could schematically refer to the historical pattern of development of the modern general equilibrium linear models in order to create an impression as to the remarkable flexibility, scope of coverage, and mathematical pregnancy of these models:

Historically, input-output analysis, linear programming, and game theory developed independently of one another.[133] In fact, the

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[133] Game theory was first introduced by John von Neumann, "Zur Theorie der Gesellschaftsspiele," Mathematische Annalen, vol. 100, 1928, 295-320; later it was systematically exposed in a large volume: J. von Neumann and Oskar Morgenstern, The Theory of Games and Economic Behavior, Princeton, New Jersey: Princeton University Press, 1944. Input-output analysis was the second of the three branches of linear economics to appear. Leontief published the first clear statement of it in W. W. Leontief, "Quantitative Input and Output Relations in the Economic System of the United States," Review of Economic Statistics, XVIII, August, 1936, 105-125. The full exposition of the method appeared in Leontief, The Structure . . . 1951.

The last of the three branches of linear economics was linear programming. It was developed by George B. Dantzig in 1947 as a technique for planning the diversified activities of the U.S. Air Force.

former two developed by independent research by Russian and American mathematicians.[134]

The connection between the three was not perceived for some time after the three distinct class of problems and their solution were well known.[135] But later development revealed the essential similarity in their mathematical structure. The economic interpretation of these mathematical uniformities has led to fascinating results.[136]

On the empirical side much effort is needed to establish a workable statistical correspondence between the existing data and the proposed theoretical categories of the above frameworks. The problem of data classification is of central importance with this regard. Dantzig has extensively exposed the nature of the problem in connection with linear programming.[137] The works in connection with input-

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The principal paper appeared as G. B. Dantzig, "Maximization of Linear Function Subject to Linear Inequalities," in T.C. Koopmans (ed.).

[134]For the Russian developments see D. I. Oparin, Multi-Sector Economic Accounts, trans. P. F. Knightsfield, New York: The Macmillan Company, 1963; and V. S. Nechinov (ed.), The Use of Mathematics in Economics, trans. ed. A. Nove, Cambridge, Massachusetts: The M.I.T. Press, 1964, pp. 1-32.

[135]See Dorfman, Samuelson, and Solow, pp. 4-5.

[136]See, for example, the discussion of "dual problems" in connection with the Leontief dynamic intertemporal model as discussed in ibid., pp. 339-340.

[137]See George B. Dantzig, Suggestions on Classification Problems in Linear Programming, U.S. Air Force Pamphlet.

output analysis constitute a major portion of the subject matter in the remaining chapters.

It may be noted that the full synthesis of the three approaches is yet to develop. It continues to be true that input-output models are being applied mostly to the problems of national economies, whereas linear programming applications are mostly limited to intra-corporation economics. But as a historical generalization it can be said that just as the rise of market economy and its cell-form, owner-manager type of business enterprise, necessitated and led to the discovery of double-entry bookkeeping--which in turn facilitated further growth in the efficiency of the enterprise--the rise of "mixed economy"--essentially non-market in character--led to the discovery of game theory, input-output analysis, and linear programming. It is significant that these problems, having been motivated by and formulated in terms of phenomena of economic life, are increasingly finding applications in engineering and physical and natural sciences.[138]

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[138] The significance of economic phenomena as a source of mathematical problems is, of course, not limited to the above three models. The celebrated American mathematician Bellman writes that economics is a "prolific source of problems involving differential equations." Richard Bellman, Modern Elementary Differential Equations, Reading, Massachusetts: Addison-Wesley Publishing Company, 1968, p. 20; for a demonstration of some such problems see pp. 20-22.

E. Modes of Inference in Science

The methods of investigation in science employ certain logical operations, which consist in various methods of inference, i.e., of reasoning asserting the truth of certain statements on the basis of the truth of other statements.[139] Contemporary logic distinguishes between three basic types of inference: <u>deduction</u>, <u>induction</u>, and <u>reduction.</u>[140]

Deduction consists in drawing of conclusions from premises. Induction refers to the drawing of general conclusions from premises which are particular cases of these conclusions. Finally, reduction is the justification of premises on the basis of conclusions drawn from them. Thus, reduction consists in reversing the direction of deductive inference.

Induction involves abstraction from the observed phenomena. Often a rudimentary classification of the observed phenomena suggests itself such as, for example, in a classification of plants on morphological grounds. Thus, scientific categories are derived from the

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[139]Strictly speaking, induction is not a form of inference, although in certain cases it is a special case of deduction, in which case it is no longer a distinct type of inference. These difficulties will be ignored in the discussion that follows because only an overview of the methodology of science and its relevant logical concepts is of interest here. For a detailed discussion of this point see the excellent exposition by Cohen, Chapters XIII and XIV.

[140]Lange, p. 133. <u>Political Economy. . .</u> , p. 133.

study of real processes of nature. Further abstraction and the discovery of relationships among categories leads to the construction of theoretical models and generalizations in the form of scientific laws. At this stage, deduction plays an important role.

Finally reduction makes the processes of verification of the constructed model possible. Here some of the theorems--that is, implied propositions--of the theory are confronted with facts. Often this is a very difficult task for its involves the translation of abstract categories of the theory into concrete classes of objects or processes. It is necessary to establish which elements of reality correspond to the theoretical concepts, i.e., those elements of reality which are considered to be equivalent to the theoretical categories must be identified. This is what Lange calls the problem of "practical identification" of categories.[141] Lange notes that "this problem is found in all economic sciences dealing with concrete economic processes--and therefore in descriptive economics and economic history, and with particular clarity in economic statistics. It most frequently appears in these sciences in the form of the problem of classification and aggregation of concrete elements of the economic process."[142] (Emphasis added, M.M.)

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[141] Ibid., pp. 121-122. As Lange notes, this problem is common to all sciences. For instances of it in physics see G. Y. Rainich, Mathematics of Relativity, New York: John Wiley and Sons, Inc., 1959, pp. 106, 113, 145, 160, especially 169.

[142] Lange, Political Economy . . . , p. 121.

It should be noted that the problem of "practical identification" as described above is not the same as the, so-called, "identification problem in econometrics,"[143] though the two are related.

After the practical identification of the theoretical categories the conclusions derived from the theoretical model can be compared with reality. If the comparison is favorable, within a predetermined statistical tolerance limit, then the theory is verified through the reductive procedure which evaluates the truth of premises on the basis of the truth of conclusions. Otherwise the model fails to conform to reality with the given standard of accuracy.

The various tests of the static Leontief model are excellent examples of this type of reductive procedure. Unfortunately a discussion of these tests would demand a lengthy digression.[144]

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[143]The problem of identification in econometrics arises in a situation such as the following: A functional relationship is statistically estimated between price, on the one hand, and supply or demand, on the other, the empirical data used being time series of prices of commodities and quantities of commodities sold. It is not clear whether the empirical relationship obtained represents a demand function, a supply function, or neither. Special methods have been developed to make approximate identification possible. For detailed discussion see J. Johnston, Econometric Methods, New York: McGraw-Hill Book Co., Inc., 1960, pp. 244-252.

[144]For a review of these tests see Hollis B. Chenery and Paul G. Clark, Interindustry Economics, New York: John Wiley and Sons, Inc., 1967, Chap. VI; also see Leontief, The Structure . . . , pp. 178-186.

The above comments indicate that all three methods of inference are needed in scientific investigation. Without induction, deductive inference would be based on premises unconnected with reality; it would not be inference relating the real phenomena.[145] Without reduction it would not be possible to state whether or not the results of induction are true, it would not be possible to verify these results. Finally, without deduction there would be no transition from the results of induction to verifiable conclusions making it possible to state whether the results of induction are true.[146]

With regard to the interplay between facts and abstract theoretical notions related to them the following passage from Whitehead is worth quoting:

> Classification is a halfway house between the immediate concreteness of the individual thing and the complete abstraction of mathematical notions. . . . But in the procedure of relating mathematical notions to the facts of nature, by counting, by measurement, and by geometrical relations, and by types of order, the rational contemplation is lifted from the incomplete abstractions involved in definite species and genera, to the complete abstractions of mathematics. Classification is necessary. But unless you can progress from classification to mathematics, your reasoning will not take you very far.[147]

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[145] Lange, Political Economy . . . , p. 135.

[146] Ibid., pp. 135-136.

[147] Whitehead, p. 43.

Here, Whitehead is referring to the necessity of moving from the natural-history, inductive state go a deductively formulated theory. In fact, this type of transition has occurred in many areas of science in their historical development from a purely observational and/or experimental stages to an axiomatic formulation. This is not only true of physics, chemistry, and astronomy, but also of geometry, which was for the first time given an axiomatic treatment by Euclid. In the words of Northrop:

> . . . Any empirical science in its normal, healthy development begins with a more purely inductive emphasis, in which the empirical data of its subject matter are systematically gathered, and then comes to maturity with deductively formulated theory in which formal logic and mathematics play a most significant part. Geometry, for instance, began with the earth measurements of the ancient Egyptians and early Greeks and came to maturity in the deductively formulated Elements of Euclid. Physics took the whole of the Greek period and the entire Middle Ages to develop its early natural history phase, and passed to deductively formulated theory when Galilei discovered its new key primitive concepts and Newton, taking Euclid's geometry as his model, generalized Galilei's concepts and developed them systematically in the deductive theory for mechanics which constitutes his famous Principia. These two stages in the normal healthy development of an empirical science are (a) the natural history stage and (b) the stage of postulationally prescribed theory.[148]

Such attempts to arrange the steps of development of science, though suggestive and containing an element of truth, can easily lead to an oversimplification of a very complex process. In the early parts of

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[148]Northrop, p. 134.

this chapter it was pointed out that "pure observation" and "pure fact" are nonexistent because consciousness in man as well as animals is selective, being directed towards certain aspects of phenomena leaving others outside the sphere of attention. Many other aspects of the interrelation between facts and concepts were investigated with concrete examples from biology and other sciences. It was seen that concepts need, as their raw material, observed phenomena, but observation is not free from the mode of operation of human mind, particularly its concept-forming activity. Hence, there seems to be a circularity--a feedback--in the process of cognition. Initial impressions and perceptions lead to concepts, concepts make it possible to perceive and/or observe new phenomena or new aspects of the familiar phenomena. Cohen expresses this process in the following manner:

> In the process of gathering and weighing evidence, there is a continuous appeal from facts to theories or principles, and from principles to facts. . . . The method of science is thus essentially circular. We obtain evidence for principles by appealing to empirical material, to what is alleged to be 'facts'; and we select, analyze, and interpret empirical material on the basis of principles. In virtue of such give and take between facts and principles, everything that is dubitable falls under careful scrutiny at one time or another.[149]

Perhaps one should say that the method of science is essentially spiral. That is, the Northropian "stages" and the Cohenian

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[149] Cohen, p. 396.

"circularity" are not inconsistent explanations; rather the "linearity" of "stages" and the "circularity" of "feedbacks" together describe the "spiral" form of motion in the development of sciences. Indeed, a close reading of the above quotations and reference to the contexts of the two shows that both authors have in mind a spiral line of development even though they have chosen to use their own special terminologies.

In order to get around the circularity of the scientific method and reveal the expository significance of his stages, Northrop distinguishes between two types of concepts: "concept by inspection" and "concept by postulation."[150]

A "concept by inspection" is one the complete meaning of which is given by something immediately observable. Thus when Linnaeus described flowers in terms of the color and shape of their petals, he was formulating a biological science in the natural history stage in terms of concepts by inspection. Scientific papers which present pictures of the structure of cancer, or the shape of the salamander, resort to the same type of concept.

But, as explained earlier, even in this natural history stage with its preponderant emphasis on induction, one does not have "pure

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[150] Northrop, pp. 136-140.

fact" apart from all concepts and theory. When facts are described, abstraction is inevitable:

> . . . Every description throws individual observed data into classes with respect to some abstracted character. These classes will fall within each other as species within genera. Since Aristotle, it has been realized, as . . . Whitehead in our own time has repeatedly emphasized, that there are many possible modes of abstraction from the same observed data, defining many possible principles of classification. Thus it becomes inevitable, even in the most emphatically inductive natural history type of science, that inescapable elements of theory are present.[151]

Nonetheless, Northrop insists, scientific theories in natural history stage are inductive to a degree and in a sense which is not true of theories in the next stage of development of a science. This happens because the theories of the natural history stage are developed entirely in terms of "concepts by inspection." What each concept in the theory means is given by something directly apprehended.

The next stage is characterized by the introduction of an entirely new type of concept--a "concept by postulation."

"A concept by postulation is one the meaning of which is proposed for it by the postulates of the deductive theory in which it occurs."[152] Thus, one does not determine the meaning of a concept by postulation by inspecting something which is directly observable;

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[151] _Ibid._, p. 137.

[152] _Ibid._, p. 139.

instead, one must examine the postulates of the deductive theory in which the concept occurs.

Since it is possible to postulate entities and structures quite different from any immediately observed, science is able to introduce, by recourse to concepts by postulation, unobserved entities and structures into its theories. The existence of such scientific objects is nevertheless verifiable.[153]

This verification, as described in more general terms earlier, consists in deducing theorems from the postulates of the theory and confronting the "concepts by postulation" in the deduced theorems with the concepts by inspection denoting the immediately apprehended data. This is what was referred to above as Lange's problem of "practical identification." Northrop calls it the problem of "epistemic correlation."[154]

> When the directly observable epistemic correlates of the deduced theorems of the postulationally prescribed theory are naturally or experimentally observed, the theory is confirmed. If they are not observed or the inspected data are contrary to what is called for, the theory is rejected. In the case of confirmation, a theoretical investigation of alternative hypotheses is pursued, with the purpose of showing as far as is possible not merely that a given theory is

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[153] Ibid., p. 150.

[154] Northrop defines this term as follows: "An epistemic correlation is a relation joining an unobserved component of anything designated by a concept by postulation to its directly inspected component denoted by a concept by intuition;" see Northrop, p. 119.

> confirmed by the data, but also that it is the only theory which is so confirmed.[155]

This concludes a synoptic overview of the method of sciences with particular interest around the idea of induction.

F. Summary and Conclusion

This chapter is concerned with the goal, nature, and method of science. It was proposed that the goal of science is primarily that of narrowing the realm of necessity and widening that of freedom for man. This is possible only through the knowledge of the laws of nature for "freedom is the appreciation of necessity" and the laws of nature necessarily exist--and exist objectively, independent of human caprice, whim, etc. The task of science is not to dream or wish these laws, these necessities, away, but to understand them. Man is ruled by that which he does not understand; he rules that which he understands.

Because it deals with objective reality--whether the physical universe or human social existence--the approach of science is fundamentally the same regardless of the specific aspect of reality which happens to be the object of interest. In fact, in order to study the general characteristics of various sciences it is necessary to abstract from the specificities of particular fields of scientific investigation.

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[155] Ibid., p. 151.

This is the task of epistomology--the theory of knowledge.

Plato saw reality as the manifestation of ideal, perfect "forms." Hegel saw reality as a historical process--the process of "unfolding of Reason." Both these philosophers were, epistomologically speaking, idealists. That is they ultimately reduced reality to mental phenomena. Berkeley and Mach were also idealist in the above sense.

The beginning of the modern era was philosophically characterized by the rise of a new epistomology: Francis Bacon founded the school of British Empiricism: Newton, Hume, Hobbs, and Locke. This school of thought derived consciousness from objective reality rather than following the idealists in treating "Idea," "Form," and "Reason" as having independent existence prior to a set of concrete experiences by human individuals. For the British empiricists reailty was ultimately reducible to "sense perceptions" or "experiments."

If reality abides not in the emphemeral entities of "Reason," "Form," and "Idea," but in the concrete existence of things and processes, it follows that it is discoverable not by suppositions about the "essence" of things but by a systematic observation of things and processes as they are, that is, by studying their "natural history." This is what Bacon advocated.

Reflection reveals that observation is not independent of concepts and generalizations unless it is interpreted in a very narrow sense in which case it becomes insignificant for the purpose of science.

In a <u>particular</u> setting men use their <u>general knowledge</u> of things and processes to observe a particular thing or process. The <u>general knowledge</u> of a man is the result of many particular experiences which are synthesized into a whole--human consciousness.

But the specific nature (or mechanism) of the interdependence between observations and concepts (or notions, or theories) cannot be studied in general terms. The level of abstraction appropriate to epistomological considerations must be abandoned in favor of a lower one which permits the investigation of the actual mechanism of scientific observation, classification, generalization. For this purpose biology and psychology were selected as concrete mediums for the study of some general methodological considerations.

Biology exemplifies the significance of what Northrop calls the "natural history stage" of science--the inductive Baconian approach. Psychology, on the other hand, is characterized by its gigantic superstructure of theories built on a very narrow empirical base. In this respect the latter offers an interesting methodological analogue to economics.

It was shown that biology started from a very primitive classificatory system where the plant and animal species were grouped on morphological grounds. With the dramatic increase in factual materials that occurred during the era of geographic discoveries, the system of classification in use became incapable of ordering all the available facts in a coherent, unified and consistent whole. The shift to a more theoretical basis was evident. The present phylogenetic basis of classification which groups species according to their "reproductive isolation" is the result of some three centuries of observation and theorizing with Linnaeus (1707-1778) and Darwin (1809-1882) as two giant empiricists in this field.

In psychology the classificatory work on mental disorders have been one failure after another. Such systems, lacking a theoretical foundation, have been based on observable characteristics. But this has been for the most part a fruitless task due to extreme variability and existence of functional dependence among the various symptoms.

With the wide acceptance of Freudianism the task has become even more hopeless. Freud introduced a fantastic theoretical system, starting with nothing but few suppositions. What is known as his "clinical observations" were essentially the results of interpretation of patients' dreams reported by them as he assisted them by the technique of "free association." Thus, his observations presuppose the validity of the methods of dream interpretation and free association.

An alternative to Freud's subjective approach is Pavlov's objective approach which traces mental phenomena to the operation of the cerebral physiology. Hence, psychic pathology must find its roots in cerebral pathology. The latter can be studied experimentally. Pavlov's methods and his theory of conditioned and unconditioned reflexes showed a pathway in this direction. Psychology illustrates a classic example of persistent frustration of a science in the face of multitude and variability of facts. It shows how futile it is to attempt to order facts into a consistent whole without access to a theory which would serve as a guide.

In economics the activities of observation and recording of data is separated from theoretical work. The former is done by the various governmental and private agencies not for the purpose of analysis but as a by-product of record-keeping activities related to their legal and/or administrative responsibilities.

Early in the development of economics the study of business accounting and economic measurement was inseparable from the study of economics _per se_. Then the two separated and have remained essentially separate to this day. However, the complexities of the giant corporation is demanding a systematic approach to the collection and interpretation of vast amounts of intra-corporation data. Without a theoretical framework it is impossible to synthesize these data into a meaningful whole. Linear programming, process analysis, and input-output models are among such frameworks.

Thus, once again the work of the theoretician has become inseparable from data collection and observation. He must indicate what and how data should be collected. Here the problem of classification of data is not a mere nuisance that can be brushed aside by the theoretician as too mundane to be of interest. It is the very bridge between the theoretical model and its actual application. Without identifying what theoretical category each concrete fact belongs to the theoretical model cannot be converted into a statistical analogue of the actual process or operation under investigation. This identification of things and processes in relation to specific categories they belong to is called the process of "practical identification" by Lange.

The last part of the chapter is concerned with the interdependence between induction, deduction, and reduction as the three components of the scientific method. Induction consist in the drawing of general conclusions from premises which are particular cases of these conclusions. Observation and systematic arrangement of facts belong to inductive inquiry. However, soon or late in the development of a science the systematic arrangement of facts becomes dependent on a deductively formulated theory.

Deduction consists in the drawing of conclusions from premises. Reduction, on the other hand, seeks the justification of premises on the basis of conclusions drawn from them. Thus, reduction consists in reversing the direction of deductive inference.

The continuous interplay between induction, deduction, and reduction constitutes the very essence of the scientific method. Neither can be functional of any value without the help of others. Without induction the deductively formulated theory lacks an intimate relation with reality. Without deduction the multitude of facts hide their nature, making themselves unintelligible to human mind. Reduction is a method of checking the degree of correspondence between a theoretical supposition and the empirical reality.

Any science that ignores this inescapable interdependence among induction, deduction, and reduction is bound to seriously depart from its goal--that of understanding reailty.

In the next chapter some methodological problems in economics will be studied against the background of the materials in this chapter.

CHAPTER III

ECONOMICS AS AN EMPIRICAL SCIENCE: PROBLEMS IN EPISTOMOLOGY, METHODOLOGY, AND ANALYSIS

1. Introduction

Until recently economic theorists and economic empiricists have worked in almost complete independence, dichotomizing the science into two separate compartments with little or no interaction between the two. This chapter studies some aspects of this phenomenon. This is a fundamental methodological problem facing the science. Being fundamental, it is natural to find its various manifestations at all levels of economic inquiry, from the most specifically formulated problems to the most abstract considerations with regard to the nature and significance of economic observations, points of departure for theoretical analysis, notions of objectivity (as opposed to subjectivity) of economic magnitudes or relations, concepts of economic interdependence, and economic structure.

Therefore, considerations about methods, analytical schemes, and philosophical presuppositions and implications become essential.

Section 2 examines the method of "intellectual experimentation" which consists of a deductively formulated model--a simplification of reality--in order to grasp the essential features of the complex economic life. It is concluded that this type of deductively-formulated theory which is held to stand by itself is of little empirical significance. The method is essentially at variance with the scientific method which consists of perpetual interplay between induction, deduction, and reduction. The method by-passes the so-called "natural history" stage of its development to the detriment of economics as an empirical science.

Section 3 examinesthe method of "idealization" in economics and shows that there is little similarity of any substance between "ideal systems" in economics and those in physics, and that frequent references to the physical ideal systems such as "ideal gas," "ideal pendulum," etc., found in the economic literature are utterly misleading and have no methodological justification whatsoever.

Sections 4 and 5 examine the question of significance of technological information in the economic science. It is shown that the aggregative concepts of overall production function cannot serve economics usefully for they suppress the immense qualitative differences that characterize the actual process of production and prevent economics from assimilating this vast amount of facts which would help the science to assume a more empirical character, coming closer to being a quantitatively verifiable science.

Section 6 introduces the notion of "order of nature" and concludes that the concept of invariance constitutes the generic feature of all types of "order" in nature. The nature and meaning of invariance in economics is examined and it is concluded that this concept is essential in empirically-oriented economic models. Classificatory systems in other sciences, as in economics, aim at capturing the essentially invariant relationships that exist in the real world. Economic invariances are shown to have their roots in the essential inertia of the technological and social processes: habits, customs, and institutionalized behaviors.

Section 7 discusses certain methodological features of economics under the titles "theoretical typicalism" and "theoretico-empirical aggregationism." It is shown that both these features indicate aspects of an anti-empirical tendency in economic analysis.

In Section 8 certain subjectivistic tendencies in economics are examined and the relationships between praxiology--the science of rational behavior--and economics are partially explored. It is concluded that there exists a certain dominant tendency in economics to treat the science as a branch of praxiology. This in reality amounts to the liquidation of economics as an empirical science.

Sections 9 and 10 deal with certain vehicles of economic analysis: partial and general equilibrium and econometrics.

Thus the dichotomy between theoretical and empirical economics is examined in several of its essential aspects. It is generally proposed that classification of facts and disaggregation of theoretically-formulated concepts and relations is the only bridge that can relate economic theory to the observed reality of economic life and move economics forward towards the status of an empirical science.

2. General Considerations Concerning Methodology in Economics

The dominant method in economic analysis is "the method of intellectual experiment."[1] Boulding describes this method as follows:

> . . . What we do is to postulate, in our own minds, economic systems which are simpler than reality but more easy to grasp. We then work out the relationships involved in these simplified systems and, by introducing more and more complex assumptions, finally work up to the consideration of reality itself.[2]

That this is the generally accepted conception of the method of economic analysis is taken for granted in the following discussion. Similar quotations can be found throughout the literature from the

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[1] K. E. Boulding, Economic Analysis, Vol. I: Microeconomics, 4th ed.; New York: Harper and Row Publishers, 1966, p. 11.

[2] Ibid.

most elementary textbooks to advanced treatises.

Now, the most distinguishable feature of Professor Boulding's exposition above is its entirely subjectivistic formulation. It makes no reference to a necessity of confronting the economic system to be postulated in "our minds" with reality. There seems to be no need for checking "the consideration of reality itself" with the objective reality. As if "the consideration of reality" is necessarily the very reality being considered. But there is no assurance that there are unmistakable paths leading one from a system postulated in one's mind to the objective reality.

Now, it so happens that the only areas of human knowledge that come close to being self-sufficient entirely in themselves are logic and mathematics.[3] Here the truth of conclusions is implied by the postulates. That is, one can systematically move, in accordance with certain rules of logic, from one set of propositions to another, with no reference to things external to these rules and propositions. This may be called a purely intellectual exercise. It is no different than Professor Boulding's "intellectual experiment." Indeed, this identity has not gone unnoticed by Professor Boulding who, however,

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[3]Even here the axioms as well as the laws of logic are not entirely independent of experience. Unfortunately an attempt to substantiate this view would lead to a lengthy digression, which is not justifiable here.

prefers to refer to it as "analogy with mathematics"[4] instead of the more descriptive connotation "the identity with mathematics."

He notes that "this method is similar in a great many respects to the method of pure mathematics."[5] He elaborates:

". . . In so-called pure economics we . . . start from simple assumptions and deduce from them conclusions which necessarily follow."[6] [Boulding's emphasis.] He continues: "The propositions of pure economics, therefore, are all hypothetical propositions."[7] [Boulding's emphasis.]

Professor Boulding proceeds to speculate about a "non-Euclidean economics."[8] He says that "it would be quite possible to build up any desired system of economics, depending on the initial assumptions taken. Just as it is possible to have non-Euclidean geometries in mathematics--that is, geometries whose fundamental axioms do not correspond to the facts of our ordinary experience--so there can be non-Euclidean systems of economic relationships in

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[4]Boulding, p. 11.

[5]*Ibid.*

[6]*Ibid.*, p. 12.

[7]*Ibid.*

[8]*Ibid.*

economics whose fundamental axioms do not correspond to the facts of our experience."[9] Further on he qualifies his remarks by saying that "naturally . . . we are more interested in those assumptions which correspond most closely to reality as we know it, i.e., to the system in which we live."[10] This question of the degree of proximity to reality will be taken up in the subsequent discussion. Here, it is appropriate to follow Professor Boulding's exposition because so far his treatment has been rather abstract. It is necessary to seek more substance in the discourse.

"The method of economic analysis," writes Professor Boulding, "is to start with very simple assumptions concerning human behavior, then to discover what consequences would follow for the economic system if these assumptions were true."[11] [Emphasis added, M. M.] Thus it is said that the substance of the system to be postulated consists of a set of assumptions concerning human behavior.

As for assumptions concerning human behavior, these are of a psychological character in the form of reaction to stimuli, with choice among alternatives being the very essence of the behavioral

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[9] Ibid.

[10] Ibid.

[11] Ibid., p. 13.

aspect which is of interest. An explicit statement of this is given by Lionel Robins: "Economics is the science which studies human behavior as a relationship between ends and scarce means which have alternative uses."[12] [Emphasis added, M.M.]

By the study of human behavior is generally meant the assignment of some motives to various groups of people engaged in economic activity. Thus producers and consumers are held to seek to maximize profit and satisfaction, respectively, in the face of given constraints such as total expenditure per period which is a determinate quantity. These postulates are said to be self-evident, though some economists do not agree with this claim. Before considering such differences of opinions, however, a precise statement of the issue will help to clarify the argument:

"The propositions of economic theory," writes Lionel Robins, "like all scientific theory, are obviously deductions from a series of postulates. And the chief of these postulates are all assumptions involving in some way simple and indisputable facts of experience relating to the way in which the scarcity of goods . . . actually shows itself in the world of reality. . . ."[13] [Emphasis added, M.M.]

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[12] Lionel Robins, An Essay on the Nature and Significance of Economic Science, 2nd ed.; London: Macmillan, 1946, p. 16.

[13] Ibid., p. 78.

This alleged simplicity and indisputability of "facts of experience" is disputed by Koopmans on the grounds that many essential aspects of consumer behavior are left out. Specifically, consumers are denied "such privileges as the joy in random variability in consumption, as well as its opposite, the comfort of consumption habits somewhat rigidly maintained under varying circumstances."[14] Koopmans lists a number of other factors. Lange adds other factors such as the interference of persuasive advertising with the "rationalization of household activity."[15] Koopmans remarks that similar "realistic" objections have so frequently been made with regard to the two postulates of entrepreneurial behavior known as "profit maximization" and "perfect competition" that there is no need for their repetition.[16] The controversies are, of course, of long standing and it would be impossible to present even a sample of the arguments involved.[17] An exhaustive

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[14]Tjalling C. Koopmans, Three Essays on the State of Economic Science, New York: McGraw-Hill Book Co., 1957, p. 137.

[15]Oscar Lange, Political Economy . . . , p. 261; Lange presents several interesting quotations from Vance Packard, The Hidden Persuaders, New York: 1958.

[16]Koopmans, p. 78.

[17]A selective set of the main works may be given: J. N. Keynes, The Scope and Method of Political Economy, New York: 1955; T. W. Hutchison, The Significance and Basic Postulates of Economic Theory, London: 1938; R. F. Harrod, "The Scope and

review of these controversies is, furthermore, not necessary for the purpose of this study. This point should become evident as the argument proceeds.

It should be pointed out that the above criticism by Koopmans is not necessarily waged against the purely postulational method as such but against the nature and "realism" of the postulates. Koopmans is concerned with "refinement" or "improvements" not with the method as a whole:

> Let us . . . ask ourselves . . . whether we can glimpse some directions in which greater realism can be attained by the introduction of further refinements or improvements into the system or systems of postulates underlying economic analysis. In particular, we should seek greater clarity on the question whether the class of postulates that impressed Professor Robins by their obviousness has perhaps by now been exhausted. If so, the 'casual' empiricism which has seemed for a time to be a sufficient basis for economic analysis would have to be superseded to an increasing extent by more systematic observation and direct or indirect testing of postulates.[18]

In the following passage Koopmans show the identity of his conception of the method of economics with those of Boulding and Robins even more emphatically:

Method of Economics," Economic Journal, XLVIII, September, 1938, 383-412; Milton Friedman, "The Methodology of Positive Economics," Essays in Positive Economics, Chicago: University of Chicago Press, 1953, pp. 1-43; Max Weber, On the Methodology of Social Science, trans. and ed. E. A. Skils and H. A. Finch, New York: The Free Press of Glencoe, 1949; for additional references see footnotes 12 and 14.

[18] Koopmans, p. 150.

> . . . We look upon economic theory as a sequence of conceptional models that seek to express in simplified form different aspects of an always more complicated reality. At first these aspects are formulated as much as feasible in isolation, then in combinations of increasing realism.[19] (Koopmans's emphasis)

Where Koopmans differs from the other two already mentioned is in his emphasis on the role of uncertainty and incompleteness of information, aspects that Koopmans considers to be not incidental but fundamental to the behavior of economic agencies. He alleges that Robins's "casual empiricism" can be replaced by "systematic empiricism" characterized by preoccupation with "systematic observation and direct and indirect testing of postulates." (See the quotation above). As to whether the postulates can be tested or precisely what constitutes systematic observation, Koopmans seems to hold that an explicit account of the role of uncertainty is the key.[20]

As things stand the lack of operational usefulness of economic theory is clearly evident in the context of the following passage from Koopmans:

> The temptation to identify the results of existing economic theory with economic theory as such--and to disqualify both in one breath--is strongest for the

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[19]This view is scattered throughout Koopmans's discussion. See specifically Ibid., pp. 146-147, 149, 150, and 155-161.

[20]Ibid., p. 150.

> experienced economic advisor to government or business, to whom the limitations of existing theory are most painfully apparent. One can hear such feelings reverberate in statements made at professional meetings by outstanding leaders of the economic profession, who in their younger days made important contributions to economic theory.[21]

In the last chapter it was shown how psychologists are utterly helpless in a systematic classification and identification of mental phenomena in spite of the impressive theoretical construction of Freud. The Freudian system was appraised from a methodological viewpoint and it was shown that it consists of a deductively-formulated theory built upon a narrow base of empirical observations. It was shown, furthermore, that these observations were not independent of the theory; to the contrary they cannot be made without the application of the theory itself. As such, the Freudian system provides a most remarkable instance of "intellectual experimentation." Too bad that such "intellectual experiments" are of little help to the practitioner!

In the discussion of methodology of empirical sciences it was shown how the Freudian system violates the accepted method of sciences by limiting itself to deduction.

Now, economic theory finds itself in a similar situation. But economists express less anxiety with respect to this state of affairs than their counterparts among psychologists. In fact, one detects

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[21] Ibid., p. 147.

not only a sense of complacence but occasionally also one of pride in this regard. Koopmans expresses himself as follows:

> The theories that have become dear to us can very well stand by themselves as an impressive and highly valuable system of deductive thought, erected on a few premises that seem to be well chosen first approximations to a complicated reality. They exhibit in a striking manner the power of deductive reasoning in drawing conclusions which, to the extent one accepts their premises, are highly relevant to questions of economic policy. In many cases the knowledge these deductions yield is the best we have, either because better approximations have not been secured at the level of premises, or because comparable reasoning from premises recognized as more realistic has not been completed or has not yet been found possible. Is any stronger defense needed, or even desirable?[22]

Others are less willing to let theories stand by themselves as "impressive systems of deductive thought" and refer to the need for empirical relevance in theoretical work. Mrs. Robinson admits that "the gap between the tool-makers and the tool-users is a distressingly wide one, and no economist can fail to have sympathy with the impatience of the politician, the businessman, and the statistical investigator, who complain of the extremely poor, arid, or even misleading information with which the analytical economists provide him."[23] But she holds that this state of affairs should in no way discourage the

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[22] Ibid., p. 142.

[23] Joan Robinson, The Economics of Imperfect Competition, London: Macmillan and Co., Ltd., 1964, p. 1.

theorists. However, it should induce him "to elaborate his analysis so much that it can begin to be useful."[24] As for the practical man, he "must be asked to have patience, and meanwhile the economist must perfect his tools in the hope of being able sooner or later to meet the practical man's requirements."[25]

Elaboration of analysis is seen as a way of bringing economic theory closer to reality, because "the more complicated the analysis, the more complicated the assumptions upon which it will work, and the nearer assumptions can be made to the complicated conditions of the real world."[26] Thus Mrs. Robinson sees her task as elaborating economic analysis by means of recognizing "imperfections" in the real world and modifying the theory by departing from the assumption of "perfect competition." She, like Koopmans, sees the system of economic theory as being essentially sound. She introduces "market imperfections," just as Koopmans would like to see the factor of "uncertainty" introduced. Neither of the two sees any weakness in the postulational nature of economic analysis.

To borrow Northrop's terminology, economic theory is conceived of by the above economists (and the majority of the members

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[24] Ibid., p. 2.

[25] Ibid.

[26] Ibid.

of the profession) to have reached its second stage of scientific evolution; namely, the stage of deductive theory formation. This implies that either the economic science has already passed through its "natural history stage" (as defined in the previous chapter) or else that there is something peculiar to economics which has enabled the discipline to side-step this stage and start its growth at a point where it took many sciences centuries to reach. It may be said that investigation of this question constitutes the innermost concern--the very core--of this study. It so happens that the substance of this core consists of the investigation of the problems of classification and aggregation. This is so because the latter constitutes the bridge between theory and fact.

Before turning to these questions specifically, however, it is necessary to examine some additional methodological features of economics--what will be referred to as "the cult of ideality."

3. On Idealization in Economics

It is fashionable among many economists to seek parallel features between the method of economics and those of other sciences. Physics, for some reason, unknown to this writer, has attracted more attention than other sciences.[27] This shows itself most clearly

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[27]Some historians of economic thought believe that Quesnay, the founder of physiocracy in France was highly influenced by the

in the terminology of economics: equilibrium, statics, dynamics, stable and unstable equilibrium, steady state solution, explosive and damping oscillation, etc. There is no particular harm in the use of such physical terms in economics provided that the terms are embodied with economic content such that a specific economic meaning is imparted by them. The advantages and disadvantages of the use of such terms is not a matter of concern here.[28] The issue is a much more substantive one. It has to do with the widely held supposition that economic idealizations are methodologically identical with physical idealizations. For example, Professor Samuelson

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Newtonian mechanics and actually developed the rudiments of the theory of competitive equilibrium in analogy with mechanics. Adam Smith who is said to have been greatly influenced by Quesnay when he visited France, further developed and popularized the system. Later work has been essentially an elaboration of this original formulation. This, however, is no more than an interesting and plausible suggestion.

Hicks writes that "the distinction between statics and dynamics is (of course) not an economic distinction. It is an echo of a far older distinction in mathematical mechanics; a reference to that older meaning will always be at the back of one's mind." See John Hicks, Capital and Growth, New York: Oxford University Press, 1965, p. 5. For some very interesting observations concerning economic dynamics see F. S. C. Northrop, The Logic of the Sciences and the Humanities, New York: The Macmillan Company, 1948, Chap. XII. Here Northrop advances the proposition that since there is nothing similar to the law of conservation of momentum in economics a theoretical economic dynamics is impossible. Ibid., pp. 244-245.

[28] For a detailed discussion see Fritz Machlup, Essays on Economic Semantics, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963, pp. 9-42.

remarks that "the requirements for absolutely perfect competition are as hard to meet as the requirements for a perfectly frictionless pendulum in physics. We can approach closer and closer to perfection but never quite reach it, a fact which need not do serious damage to the usefulness of our employing the idealized concept."[29]

Similar references are often made to the "perfect (or ideal) gas," Galileo's law understood as free fall in vacuum near the surface of the earth, Newton's law of gravitation, etc.[30] Hempel, as a philosopher of science, sees such references as unjustifiable because the idealization in natural sciences rests on entirely different principles than those in economics (and other social sciences).[31]

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[29]See Paul A. Samuelson, Economics: An Introductory Analysis, 5th ed.; New York: McGraw-Hill Book Co., 1961, p. 73.

[30]Note the following reference to physics: ". . . Consider any efficient capital program and its corresponding profile of prices and own rates. At every point of time the value of the capital stock at current efficiency prices, discounted back to the initial time, is a constant, equal to the initial value. This law of conservation of discounted value of capital (or discounted Net National Product) reflects, as do the grand laws of conservation of energy of physics, the maximizing nature of the paths." [Emphasis added, M.M.] See R. Dorfman, P. A. Samuelson, and Robert M. Solow, Linear Programming and Economic Analysis, New York: McGraw-Hill Book Co., Inc., 1958, p. 322. To speak of the conservation of discounted value of capital (or Net National Product) presupposes that these categories are operationally definable and therefore exactly measurable. This writer rejects this presupposition. The argument shall not be pursued here.

[31]See Carl G. Hempel, Aspects of Scientific Explanation and

It is true that there are physical theories such as those of ideal gases, of perfectly elastic impact, and of the mathematical pendulum, which are "idealizations" in the sense that the situations they refer to are not actually realized and may indeed be technically incapable of realization. But this should in no way imply that these idealizations are purely logical constructions that can stand by themselves. It is not true that these "idealizations" cannot be invalidated by their virtue of being "idealizations." Empirical verification of the theoretical "idealization" is not done away with because deviation from concrete fact is of the very essence of idealization. On the contrary, "idealizations" in physics are deeply rooted in empirical observation of reality. As Hempel puts it:

> The laws governing the behavior of the ideal physical systems are deducible from more comprehensive theoretical principles, which are well confirmed by empirical evidence; the deduction usually takes the form of assigning certain extreme values to some of the parameters of the comprehensive theory.[32]

For example, the laws for an ideal (mathematical) pendulum are deduced from more general principles of theoretical mechanics. The question what would happen if, say, the thread of a pendulum were infinitely rigid and if the mass of the pendulum were concentrated in the free end point of the threat is not answered by "thinking

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Other Essays in the Philosophy of Science, New York: The Free Press, 1965, pp. 164-169.

[32] Ibid., p. 168.

away" those aspects of the pendulum that are not convenient to the analysis. Instead, certain parameters of the system are assumed to approach their extreme values. For instance the parameter corresponding to the mass of the thread is assumed to approach zero. But this "idealization" still is not treated as a self-sufficient theoretical system. It is rather treated as a special case of more inclusive principles. Its role is not that of revealing the essential features of reality--such as, for example, the theory of purely competitive markets is said to do--for that reality is already explained by means of a more inclusive theory tested through verificational reduction (as discussed in the previous chapter). Hence, idealization in physics presupposes the explanation of empirical reality (to be idealized) by means of a theory of which the idealization serves a special case. In economics, however, idealizations are of the nature of explanatory constructions.

The explanatory uses of an ideal physical system such as the laws of ideal gases, in addition to their deep-seated foundation in the kinetic theory of gases, are supported by direct empirical approximations to the ideal system. Thus, Boyle-Charles law for ideal gases is rather closely satisfied by a large variety of gases within wide, specifiable ranges of pressure and temperature (for a given mass of gas), and "it is for this reason that the law can be significantly invoked for explanatory purposes."[33]

Another important feature of physical idealization is that by virtue of the existence of a more general, inclusive theory which embodies the ideal system as a special case, it is possible to judge the degree of idealization involved. For example, in the case of an ideal pendulum this is done by giving an account of additional factors which are relevant for the motion of the pendulum, but whose influence is fairly small in the case of those physical systems to which the formula is customarily applied.

In sum, there are at least three essential differences between physical and economic idealizations: Ideal systems in physics (1) have independent empirical confirmation, (2) are but a special case of a more comprehensive theory, and (3) enable one to judge the degree of idealization involved. None of these three features are present in economic idealizations.

The above argument shows that the spurious parallels drawn by some economists between their idealizations and those of physicists is utterly unfounded. There is no feature of substance which is shared by the two. One is a scientific construct formed by a continual interplay of induction, deduction, and reduction, whereas the

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[33] Ibid.

other (the economic idealization) is purely a logical construct which, as Koopmans puts it, can stand by itself.[34]

Since idealization is such an omnipresent methodological maxim in economics it is convenient to give a name to this tendency for references in the ensuing discussions. The term "cult of ideality" is introduced here for this purpose. This term will be used to refer not only to economic "idealizations" as discussed in this section but also to the method of "intellectual-experimentation" referred to in the preceding section. In a different context in this chapter, on a more abstract philosophical plane, this same characteristic of the economic method is referred to as "methodological idealism."

A systematic approach to the study of technology as one of the possible channels through which the factual base of economics may be expanded is considered in the next section.

4. Significance of Technological Morphology

For a long time anthropologists have been aware of the direct role of technology in the determination of the state of existence of a given people. From the study of tools and artifacts collected in archeological excavations (and other types of field work), they make

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[34] Koopmans, p. 150.

deductions with respect to the state of technology and division of labor, food-producing capacity, modes of existence (such as hunting, herding, and food-gathering), interrelationship with people of other localities, and many other aspects of social life. Often many aspects of the given civilization do not need separate classification because they would follow from the more "basic" data already classified. Thus the appearance of written language is not very probable unless the given civilization has reached a certain level of technical advance, say, beyond stone age, or iron age. This is not to suggest that there exist certain "key data" the availability of which would enable the investigator to deduce an exhaustive set of fundamental information about the given culture.[35] Specifically, it is not proposed that, for example, the study of tools and other artifacts reveal the essential features of the technology of the given people, and that this knowledge is a sufficient basis for knowing about all the important questions of interest: the type of marriage (if any), religion, political structure, basic social unit (family, etc.), and kinship relations. It is rather suggested that this knowledge is of primary importance because much can be deduced from it.

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[35] See Melville J. Herskovits, Economic Anthropology: The Economic Life of Primitive People, New York: W. W. Norton and Company, 1952, pp. 42-66 and 88-107; also see Paul Bohannan, Social Anthropology, New York: Holt, Rinehard and Winston, 1963, pp. 207-265.

Another important feature of technology as a useful field of observation is its objective nature. Artifacts are physical entities that can be objectively described and classified on morphological grounds. If other features of the culture which are less capable of being objectively observed exhibit a substantial correlation with the technological data, then these other features need not be observed and classified independently, because they can be deduced from the more objectively observable data.

In eccnomics, the importance of technology has attracted attention far below a degree commensurate with its importance. The classical era was much more conscious of the relevance and importance of technology than the more recent generations of economists. The passages in the works of Quesnay, Torgot, Adam Smith, and Marx on division of labor, the nature of peasant handicraft, medieval city artisans, transformation from rural household industry to the factory system, and the introduction of power machinery are too well known to be repeated here.

As the "industrial revolution" becaue a familiar process (and no more a revolution!) it ceased to impress itself upon people's minds. The factory site, mining with masses of laborers, the steam engine and cotton gin opened their place in the routine, everyday life of society; they were no longer objects of particular attention any more than trees, houses, and other familiar things and events.

Economists were no different in this regard than the rest of the people. They ceased to be curious and fascinated by the industrial processes. They lost interest not only in the state of technology as it existed but also in changes in that state; for, by passage of time, change itself became a familiar event. Thus, economists became guilty of the empirical fallacy of not noticing the familiar; and to this day they remain thus guilty. This writer knows of no work on, for example, division of labor by any economist of any period that has added anything new to what Smith and Marx had already said early in the development of economic science.[36] Indeed, what discussion is given to the students of economics in textbooks is a watered-down version of the works of the above authors in an "out-of-place," lip-service-like, and casual manner--in the form of a bewildered footnote in the style of information cataloging.

Considering the vast qualitative and quantitative changes that have so substantially transformed the technology of advanced societies relative to their state during the classical period, it is easy to see how insufficient and even in parts irrelevant are the discussions on division of labor and the state of technology provided

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[36]Reference should be made to the works of Chenery and Markowitz in this connection. These will be evaluated in a different section with specific references provided there.

by Smith and Marx. There is no doubt that economists feel that the only relevance of technology to the science of economics is that which is incorporated into the hypothetical production function. This point is of basic importance to this study and it is necessary to return to it on several occasions. This shall be done. In the meantime it is convenient to continue the discussion further along historical lines.

Ricardo championed the cause of "suppositional economics." He elevated the mysterious category of "labor" (in abstracto) to the position of the single grand category that determines all other significant economic quantities. The powerful Ricardian deductive reasoning and the "success" of his short-cuts to the understanding of economic phenomena lead to the popularization of deductive inference to the detriment of induction. The empirical base of the economic science was suppressed out of sight of the economist so that he can concentrate on aggregates in the grand style, labor, land, capital, wages fund, rent, profit, and others. There developed theories with such central concepts as "living labor," "congealed labor," "normal profit," "excess profit," and many others. Economics lost touch with reality as a differentiated whole and preoccupied itself with few magnificient theoretical aggregates. To establish necessary relations between these magnificent aggregates became the central ambition of economists. In the background the overture of Jeremy Bentham with his utilitarian universe and pleasure-pain calculus could be heard which would be followed by a century of marginal utility theorizing: Jevons, Walras, Thunen, Menger, Bohm-Bawerk, and others. Subjectivism and psychologism of the Austrian school pushed economics even farther away from the path of empirical sciences, leading more and more in the direction of an axiomatic, deductively formulated system of thought, sufficient in itself and capable of standing by itself as a logically consistent whole. This was the historical background of what is called "the cult of ideality" in a different section in this chapter.[37]

The above discussion should not be interpreted to mean that the categories of labor, capital, land, marginal utility, normal profit, and other concepts have been of no use in further understanding of economic phenomena. Rather it is the operational significance (and therefore empirical meaningfulness) of these concepts that is of concern. Were these categories derived from a set of <u>more fundamental</u> data such as technology on the producers' side, customs, habits, and tradition on the seller side, in a manner in which full account is given of the empirical differentiation (or variation) which

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[37]Epistomologically, this meant that economics submitted itself to the world of "Ideas," "Reasons," "Forms," etc., the categories of philosophical idealism. The role of philosophical idealism in the development of subjectivism in economics is a topic of immense importance in the study of economic methodology. The point shall not be followed here.

lies behind the magnificient aggregates and averages, then there would be nothing wrong, for that would amount to having an empirical science not a set of logical constructs which appeal more to one's sense of esthetics than one's sense of reality. This would be true for two reasons: (1) objectivity, and (2) relative invariance of the more fundamental data.

Before considering these two points the following remarks should be made. It is difficult to argue that micro-economics aims at providing an understanding of what lies behind the macro-aggregates. In fact the significance of the methodological distinction between macro and micro economics is itself questionable. Some aspects of this methodological approach is investigated in section 9 of this chapter. There, it is shown that the analytical method of partial equilibrium analysis which characterizes microeconomics leads to quantitative indeterminacy. As for the argument that the validity of macroeconomics does not have to be reducible to the operation of the more detailed aspects of this is no more than a negative proposition. It is only through empirical verification that the existence of such overall tendencies, more or less stable and not in need of further explanation, can be demonstrated.

The question of objectivity and invariance of custom, tradition, habits, etc., related to the consumers' side will be studied in a section on economic invariances. Here, the technological side will be discussed schematically to be further developed in a later section.

By the objectivity of technological data is meant that they are observable. Further, they are measurable; and much of the information is already available or can be obtained readily at the actual production-process level. In fact, the engineers, technicians, and plant managers cannot even operate without access to such information.

By relative invariance of technological data is meant that the data has an internal structure--a network of interrelationships--that reflects the empirical interrelationships actually existent in the economy. Thus the inertia of the technological process, which, in spite of the dynamic nature of the process, is considerable, will be reflected in the data. That is, once the empirical process is exhaustively described by the data collected and classified, then it can be continually reviewed and updated for technological changes as they are introduced. The information needed for such continual (or periodical) revisions is also available because many innivations wait for some time before they are introduced on large scale. Further, thorough familiarity with the developments at the process level facilitates the task of technological forecasting.

Having schematically introduced the notions of objectivity and relative invariance of technological data, it remains to evaluate the relevance of such data to the economic science. Such relevance has been implicitly assumed so far. However, it deserves a detailed explicit examination in a separate section. For the remaining part of this section it will be assumed that such relevance indeed does exist in a significant way.

If it is true that technological data are significant in the determination of economic quantities and if it is true that such data are objective and exhibit relative spatio-temporal invariance,[38] then some significant aspects of the economic system may be characterized quantitatively, and this quantitative characterization may be kept track of systematically.

Thus economics can be endowed with a basis which can be studied morphologically. A morphological approach to the study of technology may suggest a provisional grouping of processes (or even establishments) in order to make the vast amount of data intelligible as "classes" of data. Such practice would be useful in itself because technological taxonomy is a first step towards the creation of a technological map of the economy, one which would capture the inherent relative invariance of the empirical process, and which would reflect in detail the network of technological interdependencies among the various productive processes in the economy.

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[38] See section 6 below for elaborations on this remark.

It is doubtful whether such a technological map and its continual revision and forecasts can reveal as much to social scientists as a single artifact--say, an arrowhead of some sort--belonging to some archaic tribe would tell an anthropologist. But even a most casual reference to the role of automobiles in transformation of people's lives--work habit, geographical mobility, socio-cultural environment, ecological balances, and attitudes--is sufficient to remind one of the value of meaningful and comprehensive technological forecast. What an indispensible prerequisite for foresight and human rationality! The question is why has it been ignored for so long? This can provide a topic for an entire dissertation. Any "quick" explanation will probably be too speculative to be useful.

But, of course, purely morphological grounds sooner or later would have to yield to a more theoretically founded set of categories and concepts for mapping the technology. Just as the geological mapping of an area may begin with themost readily observable features and be followed by detailed observations of the more intricate features that most probably would escape the attention of the theoretically untrained observer, the provisional, morphologically-based approaches to the mapping of a society's technology must be followed by a theoretically sharpened sense of observation. It was seen in the previous chapter that this pattern of development actually occurred in biology and chemistry (Mendeleev's table of elements). Other examples can be drawn from paleantology, geology, natural history, and astronomy.

Already there exist economic models that provide explicit theoretical criteria for technological taxonomy. Most well known among these are the linear programming models, von Neumann, and Leontief model. The latter has been subjected to extensive empirical implementation. It will be studied in detail in this study from several angles. The von Neumann model has not been empirically implemented so far because of its demand on masses of data that are not yet available or are expensive to compile. Linear programming models have been extensively utilized by the industrial and military organizations. These models will be sketched in this chapter.

The concept of progress referred to in this section and used in a loose sense will find a rigorous definition in the context of these models.

This section may be summarized by saying that direct observation of the technological process, collection and classification of data on the basis of such direct observation--perhaps using a morphological basis for data classification as a preliminary step to be further modified and substantiated by subsequent theoretical refinement--can give an empirical base, a window of observation, and an objective sphere of inquiry into many economic problems. It will constitute a major step towards the rescue of economics from the prevailing magnificent theoretical aggregates and will help the science to advance in the direction of an empirical science as opposed to a deductively formulated body of thought. It is the great merit of general equilibrium theories in economics to have shown the precise manner in which technological processes enter economics. This point will be elaborated upon in several different contexts in this-study. One version of general equilibrium models formulated by Leontief has provided a very useful framework for displaying sectoral interrelationships in the economy. Technological morphology plays a major role in the ideal compilation of data for input-output tables which constitute the factual basis of Leontief's analytical scheme.

5. Economic Significance of Technological Data

Ever since the formulation of the classical theory of produc-production--the law of variable proportions (or diminishing return)--by Ricardo, Multhus, Torrens, and West, the economic science has failed to advance any new propositions in this area. The Lausanne School with its culmination in the works of Leontief is an exception to this general statement. But, at least until recently, the Lausanne School did not enjoy the recognition that would lead to the popularization of its views. Rather, it was treated as a curiosity: interesting but practically irrelevant. In fact, Walras and Pareto were the first to admit that their general equilibrium scheme was only of purely theoretical interest and lacked any practical value because it could not be implemented: the parameters could not be estimated because of computational difficulties.

As far as the widely accepted theories of production are concerned, the long shadow of Ricardo has kept economists in its overpowering confinement: the economist's world is the world of diminishing returns. Everything else is simply refinement, elaboration, and generalization of this principle:

The neoclassical production functions are nothing but mathematical refinements and sophistications of the law of diminishing returns. The Cobb-Douglas, CES, and the rest are all variations on the same theme. Many of the concepts evolved around these functions such as Mrs. Robinson's "efficiency units,"[39] Kahn's "ideal output,"[40] Hicks's "elasticity of substitution,"[41] etc., have been shown by Leontief to be methodologically inefficient and at least in one case--

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[39] On "efficiency units" see Robinson, p. 332; here she uses the term "corrected natural units" to refer to what Allen has popularized as efficiency units. See Allen, Macroeconomic Theory: A Mathematical Treatment, New York: St. Martin's Press, 1968, pp. 238 and 246.

[40] See R. F. Kahn, "Some Notes on Ideal Output," Economic Journal, March, 1935.

[41] On elasticity of substitution see R. G. D. Allen, Mathematical Analysis for Economist, London: The Macmillan Co., Ltd., 1964, pp. 341-343, 344-345. The concept was first introduced in J. R. Hicks, Theory of Wages, London: The Macmillan Co., Ltd., 1932, pp. 117 and 245.

that of "efficiency units"--invalid constructs.[42] He classifies these concepts as cases of "implicit theorizing." Unfortunately, a very lengthy and abstract methodological digression is required for any specific discussion of these concepts. It is more appropriate to refer the reader to the extremely significant article by Professor Leontief: "Implicit theorizing: a methodological criticism of the neo-Cambridge school."[43] By way of imparting an impression as to the nature of the issue involved the following passage from Professor Leontief's essay is given: After a critical examination of the concept of elasticity of substitution, Professor Leontief writes:

> I do not doubt that it is logically possible to find a definition of elasticity of substitution which (unlike the narrow technical interpretation) would make Mr. Hicks's standard proposition explicit, and universally true at the same time. I doubt, however, whether an intellectual _tour de force_ of that kind would yield results of greater theoretical significance than those which could be and have been already obtained, with much smaller loss of mental energy on the basis of orthodox methodological pattern.[44]

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[42] W. Leontief, "Implicit Theorizing: A Methodological Criticism of the Neo-Cambridge School," _Quarterly Journal of Economics_, LI, February, 1938; reprinted in Wassily Leontief, _Essays in Economics: Theories and Theorizing_, New York: Oxford University Press, 1966, pp. 58-71.

[43] _Ibid._

[44] _Ibid._, p. 69

The success of the law of diminishing returns and the theory of differential rent as explanatory devices lead to over a century of confinement of economics to "diminishing returns" and "marginalism." This was by no means limited to the theory of production. The Australian School lost no time in translating the law of diminishing returns in subjective terms, offering a formally identical theoretical structure for consumption behavior, with marginal and total utility taking the places of marginal and total physical output in the theory of production. Whether this was a pedantic exercise in "marginalizing" Jeremy Bentham or a keen sense of seeing the essential "oneness" in the multiplicity at surface of economic phenomena remains to be seen. That is, as far as this writer is concerned, the question of whether the Australian School did a service or disservice to economics is far from being settled. Further, the final settlement of the issue pends the development of an empirically implementable theory of consumer's behavior. Until such time, the evaluation of the theory of consumption as it stands is impossible unless one is willing to accept logical grace, structural esthetics, or rigor in deductive inference--all being characteristic features of the present theory--as a basis for evaluation. But, in that case economics ceases to be an empirical science and becomes identifiable with praxiology, that is, the study of rational behavior.[45] It is necessary to return to this point in a different context. Here the argument shall be restricted technological considerations.

The casual remark by Torgot on diminishing returns in agriculture is generalized and more exactly formulated by West, Torrens, Multhus, and Ricardo and captures the imagination of some half dozen generations of economists. This in itself is a problem of extreme interest in the history of development of the economic science. If such a primitive observation with regard to the natural and technological basis of production was so helpful to Multhus and Ricardo in their investigation of agricultural and non-agricultural prices, patterns of trade, etc., could it not be the case that even a more detailed examination of such natural and technological conditions would lead to even further results? Why did the economic science stop at a point which was only a beginning? The answer is probably a very complex one. This writer does not have it. Few preliminary hypotheses can be formulated in this regard. This would, however, necessitate an unjustifiable digression in this study. The problem can, nevertheless, be stated concisely: Economists after Ricardo preceeded as if all the knowledge needed with respect to production was already condensed in the law of diminishing returns and all there was left to do was the

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[45]Lange, pp. 188-207.

discovery of more and more areas of economics that could be subjected to the logic of diminishing returns. This meant far more than intellectual servitude to Ricardian art of "suppositionalism." It meant no less than depriving economics of one of its most fundamental empirical bases--the area of technology. Just as the Mohammedans (Moslems) see everything in the universe as the manifestation of the will and heavenly grace of Allah, the post-Ricardian economists saw everything in the economic universe as the manifestation of the "law" of diminishing returns: Diminishing returns in agriculture, in industry, for a given farm as well as the collection of all farms, for a given firm as well as all firms in an industry, for a given industry as well as all industries together, in short, for individual producing units as well as for the economy as a whole! The subjective counterpart of this in the form of marginal utility "established" (?!) the "law" as a universal law of the true economic science, true not only in production but in the sphere of consumption as well. Physicists had the law of gravitation. Why shouldn't economists have a law or two of their own![46]

The law of diminishing returns as an abstraction from the

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[46]Professor Morgenstern has directed attention to the futility of theorizing without measurement and verification; see Oscar Morgenstern, Economic Activity Analysis, New York: John Wiley and Sons, Inc., 1954, p. 494.

natural and technological conditions of production suppresses the immense qualitative and functional differences among the various inputs in a given production process by means of classifying all inputs into three magnificent aggregates: land, labor, and capital. This super-aggregative nature of the elementary concepts of the law is, by itself, sufficient to render the law devoid of any operational significance. One would have to construct indexes of highly heterogeneous inputs facing the valuation, weighting, and other familiar index number problems with no guidelines provided by the theory itself. In short, what is said of the operational difficulties in dealing with aggregates throughout this study is true of the land-labor-capital trio which lies behind the law of diminishing returns.

Further, even if the problem of aggregation in the above sense did not exist (or could be overcome), there exists another operational difficulty: It is never made clear whether the law is applicable at the level of a single process, a set of processes, a department within an establishment, an establishment, a firm, an industry, a group of industries, or the whole economy. It is tacitly assumed to be true in all the above cases. But the theory itself does not provide any guide as to how, for instance, one is to establish the truth of the law for a given firm, assuming that all the establishments belonging to that firm follow the law.

Now, suppose the two types of aggregation discussed above, that is, aggregation with respect to the elementary concepts of the theory (land, labor, and capital), and aggregation with respect to the law itself--going from one level of operation such as establishment to another, say, firm--did not exist (or could be overcome). Still the theory is operationally not significant because of its nonlinear formulation and the difficulty and/or impossibility of computational work when a large number of nonlinear relations are involved. The mathematics of linear relations is much better understood than that of the nonlinear ones. The former is highly developed theoretically, computationally, as well as in the evaluation of errors involved in the computation--a very significant factor in the empirical utility of a computed result. That is why natural sciences very often resort to linear approximations even when they have empirically verified that the true relations are of a nonlinear nature. For example, when swings in the pendulum are small, the system can be treated by linear methods; when swings are large, nonlinear techniques become necessary. Such empirical methods of approximating reality is as rare in economics as the suppositional devices of assuming things in and out of a model are plentiful. Professor Morgenstern observes that:

> It is astonishing that economists seem to hesitate far less to introduce nonlinearity than physical scientists, where the tradition of mathematical exploration is much

older and the experience with observation and measurement so much firmer.[47]

Questions of linearity and nonlinearity cannot be settled on _a priori_ grounds. It is ultimately a question of observing the _empirical_ reality itself whether any significant violation of facts occurs when linearity is assumed. The complexity of the relations assumed in mathematical economics is an arbitrary event as long as the theoretician is not compelled to assume the responsibility of considering the empirical verification of his propositions. In fact, there may develop a tendency to assume ever more complex relations in the false hope that this will bring the "model" closer to reality. "A simple analysis," writes Mrs. Robinson, "can only be made upon simple assumptions, and the more complicated the analysis, the more complicated the assumptions can be made to the complicated conditions of the real world."[48]

But this strategy of getting gradually closer to the real world through ever more complicated assumptions presupposes that Mrs. Robinson knows the _nature of the complexities_ of the real world. But rarely in history have individuals been endowed with such extra-

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[47] Oskar Morgenstern, _On the Accuracy of Economic Observation_, 2nd ed.; Princeton, New Jersey: Princeton University Press, 1963, p. 94.

[48] Robinson, p. 2.

ordinary power of intellect as assumed in the method of economics. Such Laplacian super-human intelligence which could comprehend the nature of such a vast network of interdependencies as exist in the economic life of a society can indeed serve as the principle character of a very fascinating science fiction but not as a useful assumption in any science. This superhero of the world of intellect finds its embodiment only in the body of some economists and Freudian psychologists. In the case of the latter, it is assumed that the meaning of every dream image, linguistic symbol, and uncontrolled motor activity, is known to the psychologist. Based on this assumption Freud observes (?!) the patient's dreams. Instead of the law of diminishing returns and the assumption of homo economicus (the economic man), the psychologist has his instincts of libido and death, the drama of ego, superego, and id.

The above remarks should make it clear that the specific propositions of economic theory--like the law of diminishing returns--cannot be separated from the general suppositional methodology that has dominated economics since Ricardo.[49] The specific propositions

[49] In the criticism of the present state of economic methodology and the tracing of some of the prevailing theories to Ricardo and others in the classical period, the author does not mean to discount the important contributions made by these thinkers towards the formation of the economic science. What is insignificant today was not necessarily so at the time of its original formulation. The issue is not whether, for example, the law of diminishing returns was of value

must be evaluated simultaneously with the overall methodology, otherwise one would be caught in the infinitude of examining the endless multiplicity of specific propositions based on arbitrary assumptions. Already in 1620 Francis Bacon warned against the futility of such exercise.[50]

Thus the vague[51] abstraction of an aggregative production function according to the proposition[52] of diminishing returns amounts to the suppression of all the qualitative and functional differences that characterize the true process of production. In other words, such an approach implies that the technological and other aspects of production are irrelevant to the understanding of economic

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when it was first formulated or not. Rather, it is the failure of the economic science to evaluate this hypothesis with regard to its empirical validity and the completely out of proportion role that the science assigned to the law by universalizing it, that is the issue.

[50]Bacon, Vol. XXX, 130.

[51]Vague in the sense that the domain of application is not specified as noted earlier.

[52]Strictly speaking, the assumption of diminishing returns does not even constitute a proposition. For proposition is a statement that can be identified as true or false. The law of diminishing return, as it stands, that is, without being supplemented by additional propositions, does not lend itself to empirical verification, and hence, does not constitute a proposition. For a discussion on propositions in logic see M. R. Cohen and E. Nagel, An Introduction to Logic and Scientific Method, New York: Harcourt, Brace and Company, 1936, chap. II.

phenomena except in a certain general (and operationally meaningless) way through the abstraction of diminishing returns.

It is significant to note that in two of the theoretical frameworks which have been statistically implemented; namely, in input-output analysis and linear programming, precisely those features are lacking which characterize the law of diminishing returns. That is, (1) the aggregative concepts of labor, land, capital, and abandoned in favor of highly specific inputs identified with specified rules.[53] (2) The domain of application of the theory is specified, and the problem of aggregation assumes a theoretically-particularized formulation. The theory itself provides guidelines for aggregation of the empirical data. (3) The assumption of nonlinearity is abaodoned in favor of linearity.

In order to give a specific account of the significance of technological data to economics a selected class of empirically verifiable economic models will be studied. These are the static Leontief model, the von Neumann model, and linear programming.

A. Linear Programming

In linear programming a productive unit such as an establishment, a firm, or industry is conceived of as employing a set of "activities" (or "processes") which convert a set of inputs (or

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[53]See Chapter VI for a detailed discussion of the specification of inputs through classification in input-output analysis.

resources) to a set of outputs under the qualitatively specified limitation of resources in such a way that some objective function is maximized (or minimized).

The adjective linear means that the variables involved in the model appear in additive form with exponents of zero or one only. Also no operators such as log, sin, $\tan^{-1}$, etc., are permissible.

Let a_{ij} designate the number of units of resource i which is needed for the production of one unit of output j. Suppose there are m different resources involved. Then the column vector $[a_{11}, a_{21}, \ldots, a_{m1}]$ indicates the set of resource requirements for production of one unit of output of product 1. This vector is called a "process vector." A process is thus completely identified quantitatively by the entries a_{ij} whose numerical values are to be empirically measured by observing the actual operation of the productive unit being studied.

The objective function measures the level of attainment of a certain goal which depends on the values of the set of output variables. For example, the objective function z may depend on the level of output x_j and the contribution p_i per unit of x_j to total profit. Then the objective function is given as

$$z = p_1x_1 + p_2x_2 + \ldots + p_nx_n$$

where it is assumed that there are n different outputs. x_j are assumed to be non-negative. A specified set of values of x_j such as $(x_1^0, x_2^0, \ldots, x_n^0)$ is called a <u>program.</u> Thus the task is to choose that program (or those programs) which results in the maximum value of z. Hence, the term "programming."

It is assumed that there are specific amounts of resources $R_1, R_2, \ldots, R_m$ available. Therefore, the use of each resource i cannot be larger than the available quantity R_i. Recalling the definition of a_{ij}, the quantity $a_{i1}x_1^0 + a_{i2}x_2^0 + \ldots + a_{in}x_n^0$ measures the total use of resource i when the program $(x_1^0, x_2^0, \ldots x_n^0)$ is performed. For any program $(x_1, x_2, \ldots, x_n)$ it must be true that

$$a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n \leq R_i$$

Therefore, the linear programming problem can be concisely formulated as follows:

$$\max\ z = \sum_{j=1}^{n} p_j x_j$$

subject to

$$\sum_{j=1}^{n} a_{ij}\, x_j \leq R_i \qquad (i = 1, 2, \ldots, m)$$

$$x_j \geq 0 \qquad (j = 1, 2, \ldots, n)$$

Several different computational methods have been worked out for the above problem the most efficient and widely used of which is the simplex algorithm developed by Dantzig.

To review the model: it involves variables whose values are to be determined by solving the model. These are Z, the value of the objective function, and x_j, the specific value of each output j. The parameters are of three distinct types: the objective-function parameters p_j, the resource availability parameters R_i, and the technological parameters a_{ij}. The reason for calling a_{ij} the technological parameters is that each productive process is strictly identified by the values of a_{ij}. By a technology is meant, therefore, a set of processes. Thus the matrix $[a_{ij}]$ constitutes the technology matrix of a given productive unit such as an establishment. The number of rows and columns in this matrix determines the degree of fineness (as opposed to coarseness) of the structure of the model. The coarser the technology matrix (the smaller the number of processes and resources distinguished) the less the details of information necessary for the solution of the model and the less the details of information in the solution obtained. This is a specific case of the general principle of loss of information through suppression of details (of qualitative variation) by means of aggregation.

Note that aggregation in linear programming assumes a well-defined formulation: it consists of increasing the degree of coarseness (in the above sense) of a given classificatory scheme.[54] So is the case

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[54]The problem of classification in linear programming has

with von Neumann and Leontief models.

Thus the problems of what kind of data are to be collected and how they should be classified and what are the consequences of finer or coarser classifications are all specified and guided by the theory itself. As more and more firms in the economy adopt linear programming and the related techniques of game theory and input-output analysis, the collection and classification (on a unified principle) of technological and resource-availability data proceed on an ever more universal scale and to that extent the technology matrix for the society as a whole[55] will come to be known ever more completely and with more precision. Thus economics gradually approaches the status of an empirical science based on measurements which preserve any desired degree of qualitative details. Then it would be possible to evaluate the operational significance of some of the existing aggregative economic concepts such as land, labor, and capital. Some of these concepts may turn out to be entirely devoid of any significance, others may become meaningful

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been exhaustively examined by Dantzig. See George B. Dantzig, Suggestions on the Classification Problem in Linear Programming, U. S. Air Force Pamphlet. For a comprehensive presentation of linear programming theory and its ramifications see George B. Dantzig, Linear Programming and Extensions, Princeton, New Jersey: Princeton University Press, 1963.

[55]This matrix will be introduced in connection with input-output analysis in the following chapters.

through a rigorous formulation that would indicate the precise way in which an aggregate such as "labor" or "capital" is to be built up from immediately available data. Needless to say, the wide acceptance of linear programming and input-output analysis will act as a great stimulus to the improvement of data collection practices. Further, much data which is not made available now is expected to become available in a systematic fashion. Here, then, is the case of some theories which do not shy away from the problem of factual implementation--as the case is with much of prevailing economic theories--but directly provide the principle strategies necessary for such work.

Thus linear programming involves a theory of production which is characterized by linearity, disaggregated technological data, and specification of domain of application. In all these respects it stands in sharp contrast to the neo-classical smooth production function based on the notion of diminishing returns.

B. The von Neumann Model

The von Neumann model is a pure production model which is closed in the sense that there is no final demand (consumer, government, investment, exports) and no fixed factor of production. Labor is thought of as being produced by "households" with consumption goods as inputs of the household sector. It is assumed that labor, like any other commodity, is produced by a process (or activity) defined similar to the linear programming process discussed above. Thus each unit of output of labor requires specified amounts of various commodities which define a particular process. There can be more than one process of production for a given commodity.

It is assumed that each process takes exactly one unit of time. This can be arranged even if different processes really have different duration, by introducing fictitious intermediate stages in the longer processes. The treatment of capital goods in the von Neumann model is extremely interesting. A nondepreciating capital good enters both as input (with negative sign) and as output (positive) in the process employing it. If the capital good depreciates r per cent per unit of time, one unit of it may appear as input, and $(1 - r)$ of a unit as output.

Since each process is assumed to be of exactly one unit of time after inputs are used. Since the productive system is closed the output of one period are the inputs of the next. Thus every commodity is an intermediate product. The quantities of all resources (inputs) are specified once a given instant of time is given. At any given moment, the production is limited by the currently available inputs (which are the outputs of the previous period).

Inventories can be handled by defining a process with one unit of a given commodity for input and one unit of the same commodity for output. Storage costs can be entered as inputs also, perhaps in the form of depreciation of inventory.

Now let a process j be defined by a column vector $[a_{1j}, a_{2j}, \ldots, a_{mj}, k_{1j}, k_{2j}, \ldots, k_{mj}]$ where a_{ij} and k_{ij} are non-negative numbers defining inputs and outputs of each of m distinct commodities necessary for the production of one unit of commodity j. Note that the process j may have other outputs than j. But the process is defined in terms of one unit of output of j, all the other outputs being defined in terms of j. For example if product j has two "by-products" k and l of which 2 and 3 units are produced respectively whenever one unit of j is produced then 2 and 3 constitute the output coefficients for goods k and l, consistent with the production of one unit of j.

Next let $x_j(t)$ and $x_j(t+1)$ be the amount of commodity j in times t and $t+1$, respectively. From a viewpoint at time $t+1$, therefore, $x_j(t)$ is the amount of input of commodity j and $x_j(t+1)$ is the amount of output of it.

Since the only way to produce $x_j(t+1)$ is to apply process j at time t, $x_j(t)$ which measures the level of availability of j at that time t also measures the "level" (or "intensity") of process j necessary to attain the output $x_j(t+1)$.

Recalling the definitions of a_{ij} and k_{ij} above, the total availability (supply) of commodity i at time t is given by

$$(3.1) \qquad S = \sum_{j=1}^{n} k_{ij} x_j(t) \qquad (i = 1, \ldots, m)$$

where it is assumed that there are n different processes. In order to attain outputs $x_1(t+1)$, $x_2(t+1)$, . . . , $x_n(t+1)$ it is necessary to apply inputs

$$(3.2) \qquad D = \sum_{j=1}^{n} a_{ij} x_j(t+1) \qquad (i = 1, \ldots, m)$$

of commodity i.

It is clear that the amount of inputs required cannot be greater than the available supply S. Thus $D \leq S$. That is:

$$(3.3) \qquad \sum_{j=1}^{n} a_{ij} x_j(t+1) \leq \sum_{j=1}^{n} k_{ij} x_j(t) \qquad (i = 1, 2, \ldots, m)$$

Now consider the profit side of the production process. Let $p_i(t)$ and $p_i(t+1)$ be the prices of commodity i at times t and $t+1$, respectively. Then for a unit level of operation of process j the unit cost is

$$(3.4) \qquad C = \sum_{i=1}^{m} a_{ij} p_i(t) \qquad (j = 1, 2, \ldots, n)$$

and unit revenue is

$$(3.5) \qquad R = \sum_{i=1}^{m} k_{ij} p_i(t+1) \qquad (j = 1, 2, \ldots, n)$$

In a competitive market the discounted revenue from a unit level of operation of a process cannot exceed unit costs because otherwise the process intensity would increase (output would expand) until input prices rise and output prices fall enough to eliminate the profit. Let ρ_t be the market rate of interest in period t. Then

(3.6)
$$C \geq \frac{1}{1+\rho_t} R$$

or

(3.7)
$$(1+\rho_t)C \geq R$$

where $\frac{1}{1+\rho_t}$ is the discount factor in period t. By substitution for C and R from above:

(3.8)
$$(1+\rho_t) \sum_{i=1}^{m} a_{ij} p_i(t) \geq \sum_{i=1}^{m} k_{ij} p_i(t+1) \qquad (j = 1, 2, \ldots, n)$$

Von Neumann gives a special case of this by resorting to the steady state[56] assumptions. These assumptions consist of $\rho_t = \rho =$ constant, and $p_i(t) = p_i$ = constant, on the price side; on the output side it is assumed that the process intensities in each period are proportional to those of the preceding period with the factor of proportionality α. That is,

$$x_j(t) = \alpha\, x_j(t+1)$$

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[56] In dynamics, "steady state" refers to a proportional change in the component parts of a system from one period to the next. There are three special cases of steady-state change: proportional expansion, lack of expansion or shrinkage (stationary state), and proportional shrinkage.

The economy will experience balanced growth, stationary state, and balanced shrinkage, depending upon whether $\alpha > 1$, $\alpha = 1$, or $\alpha < 1$, respectively. Incorporating these assumptions in the above relations (3. 3) and (3. 8), respectively, results:

$$(3.9) \qquad \alpha \sum_{j=1}^{n} a_{ij}x_j \leq \sum_{j=1}^{n} k_{ij}x_j \qquad (i = 1, 2, \ldots, m)$$

and

$$(3.10) \qquad (1 + \rho) \sum_{i=1}^{m} a_{ij}p_i \geq \sum_{i=1}^{m} k_{ij}p_i \qquad (j = 1, 2, \ldots, n)$$

Using a fixed-point theorem,[57] von Neumann proved that his system has a unique solution. Specifically, he showed that max (α) = min $(1 + \rho)$ is the unique rate of steady-state growth of the system. The equilibrium values of α and $(1 + \rho)$ have extremely interesting interpretations. Some of these results have been explored by Dorfman, Samuelson, and Solow.[58]

The above discussion of the von Neumann model indicates that, by its nature, it is applicable only to the economy as a whole not to its component parts. It is a dynamic theory of general equilibrium.

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[57]For a discussion of "fixed point theorems" see Dorfman, Samuelson, and Solow, pp. 371-372.

[58]*Ibid.*, pp. 387-388.

The amounts and kind of data required for it are so vast that its empirical implication in near future is not very likely. Further the structure of the theory is so fine that its solution, even if the model is statistically implemented, is beyond the capacity of the existing computing facilities. Quantitative specification of a von Neumann process requires measurement of the following types: Given a commodity such as copper wire of specified thickness, purity, etc., it must be determined what various inputs and to what amounts are needed to produce a unit of output of this commodity. How many hours of each type of labor, each type of machinery, building, how many units of fuel, electricity, copper ingot, etc., how fast the inventory is being used up or added to, and how fast the equipment and buildings are depreciated. These are the types of data that must be collected. The number of processes to be thus identified are very large, since for every distinct commodity a process is defined; and the concept of commodity in this context is much more inclusive than the more familiar one. For instance labor of various types constitutes not one but several different commodities. So is the case with other resources. Then there arises the question of measuring the inputs of a process whose output is a given type of labor. Consumption expenditures of the society must be broken down on the basis of various commodities and the related to the outputs of various types of labor. The difficulties (or perhaps impossibility) of such a task is evident.

The number of distinct commidities in the above inclusive sense is perhaps as large as several millions for the American economy. Therefore, when the quantitative specification of each individual commodity is achieved, the next step consists of different types of consumption involving several million interdependent variables. This requires an astronomical computing capacity. Perhaps such a capacity will be made available when the next couple of generations of computers are born. Presently, it is not available.

But the characteristics of the von Neumann model--which is formally of the same structure as the linear programming model in its most generalized formulation--are again diametrically opposed to the neo-classical theory of production. The disaggregated technological data, linearity, specificity of the domain of application, the types of data to be collected, an implied classificatory scheme for these data, and an exhaustive enumeration of the necessary assumptions, that is, the absense of <u>ceteris paribus</u> assumption. The model is, in principle, empirically verifiable. Its implementation is a matter of cost, availability of the specified data, and improved computing technology.

The concept of process (or activity) which underlies both the von Neumann and linear programming models, has lead to some interest, in recent years, towards technological model building.

Attempts have been made to derive highly disaggregated economic production functions from engineering data. Chenery and Markowitz are among the pioneers in this field.[59]

C. The Leontief Model

The Leontief model in a static version is extensively studied in the following chapters. Here, it will only be noted that technological data constitutes the kernel of the Leontief model just as it was the case with the preceding two models. All the essential features of the preceding models, disaggregated formulation, linearity, etc., are again present in the Leontief model. There will be a rather detailed comparison of the Leontief production function with the Cobb-Douglas function as a representative of the neo-classical production function in chapter .

6. On Invariance: An Examination of the Nature of Economic Invariance

The notion of order in nature is implied by the very existence of sciences. Whitehead writes that "there can be no living sciences

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[59]See Hollis B. Chenery, "Process and Production Function from Engineering Data," in W. Leontief, et al., Studies in the Structure of the American Economy, New York: Oxford University Press, 1953, pp. 297-325; and Harry Markowitz, "Industry-Wide, Multi-Industry, and Economy-Wide Process Analysis," in Tibor Barna, ed., The Structural Independence of the Economy; proceedings of an International Conference on Input-Output Analysis, Verna, June-July, 1954, New York: John Wiley and Sons, Inc., 1955, pp. 119-152.

unless there is a widespread instinctive conviction in the existence of an Order of Things, and, in particular, of an Order of Nature."[60]

The root of this instinctual belief in the Order of Nature is obviously not in the exact recurrence of things and events in nature, for such a recurrence is nonexistent: no two days, or two winters, are identical. What has gone, has gone forever. "Accordingly," notes Whitehead, "the practical philosophy of mankind has been to expect the broad recurrences, and to accept thedetails as emanating from the inscrutable womb of things beyond the ken of rationality."[61]

The expectation of such broad recurrences is based on the long experience of mankind with nature's general recurrences. Men have adapted themselves to nature with these expectations playing an essential role in the adaptation process.

There is a type of order that is so familiar that, in spite of its essentiality in relation to human survival and development of civilization, it generally escapes notice. Things like water, salt, and iron, are given these special names. Why? Because "water" denotes a constant conjunction of properties: it is liquid in a given temperature range, it is odorless and colorless, it removes thirst,

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[60] Whitehead, p. 5.

[61] *Ibid.*, p. 7.

etc. Thus the name "water" signifies a constant conjunction of properties, and at the same time it distinguishes this from other constant conjunctions of properties related to salt, iron, and water.[62]

The importance of this type of order is of utmost significance as a step towards the discovery of other types of physical order in the universe. This emphasis on the importance of such elementary order constitutes the very essence of Bacon's empiricism. Northrop's view of the stages of development of sciences from the "natural history stages of development of sciences from the "natural history stage" to that of deductively formulated theory shows his insistence on the importance of distinguishing between things and processes on the basis of their most immediately comprehended properties. To single out the "thinghood" of a "thing," to distinguish a thing from other things, these are essential in science as well as in practical life. Cohen is quite emphatic on this point: "The vague notion of a thing," he writes, "denotes . . . a very elementary but fundamental type of order. It denotes a certain invariable conjunction or association of properties that is different from other conjunctions. . . . The discovery of this kind of order is fundamental to the discovery of any other kind of physical order. Different kind of things have been recognized in the

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[62]This discussion is based on Cohen and Nagel, Chapter XIII.

most primitive stages of man's history. But the process of classifying and cataloging our experiences is not complete, and perhaps never will be."[63]

There is a second kind of order known as "causal order." This often involves a temporal direction. For example, the proposition "iron rusts in moist air" is generally regarded as expressing the causal relation that most air is the cause of which the rusting iron is the effect. It is difficult to make clear what is understood by causes "producing" their effects. A close examination of many alleged instances of causality reveals that these are instances of an invariable relation between two or more processes.[64]

Further, many alleged instances of causality are found, upon closer scrutiny, to be specious: Iron does not always rust in moist air. There are other factors involved. Thus one is led to seek other factors that are necessary for the occurrence of the given effect. In this way there is a gradual transition from the crude and approximate uniformities observed in everyday experience, to the more completely analyzed invariant relations of the developed sciences.

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[63] Ibid., p. 246.

[64] Ibid.

A third kind of order is often expressed by numerical equations. This is the case, for example, with the principle of the lever, which states that equilibrium is obtained when the two weights very in inverse proportion to their distances from the fulcrum.

A fourth type of order is illustrated in such comprehensive theories as the theory of gravitation, or the kinetic theory of matter. In these cases, not all the elements between which the invariant relations are asserted to hold are directly observable. Thus the atoms, their motion and collision, the invariance of their average energies, cannot be verified directly. The raison d'etre for such theories is well illucidated by Cohen:

> The function of such comprehensive theories . . . is that they enable us to show that many numerical as well as qualitative laws which are in fact experimentally confirmable, are not isolated from one another. Such laws can often be shown to be the necessary consequences of the more abstract and inclusive order asserted in the theory.[65]

Thus comprehensive theories are designed to establish a general framework for an internally consistent organization of observed and/or experimentally verified phenomena. As long as the results of experimentation and observation do not contradict a theory, that theory remains useful. So soon as such experiments or observations are made that cannot be fitted into the existing theoretical

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[65] Ibid., p. 247.

fremework, then the particular science is left without a comprehensive theory. Sooner or later more general theories will be offered which will, once more, put all the observed and experimentally-derived facts into a consistent conceptual whole. The crucial point, however, is that the theory must at all times be at the mercy of observed facts. It must, in principle, be refutable through the empirical test of its theorems. The crucial factor is not the internal logical consistency, the rigor and elegance of the axiomatic treatment, though these are desirable features, and in the case of internal logical consistency, it is a necessary condition. The crucial element in theories of an empirical science is its perpetually inseparable relations with facts. A theory is "voted in" by facts and a single negative "vote" can "vote it out" as a theory. A theory is fitted to facts not vice versa.

If the four types of order discussed above are examined closely, it will be seen that the generic feature of all four of them is the assertion of some kind of invariable relation between various kinds of elements. It is this invariance which seems to be significant both theoretically and practically.[66]

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[66]Theil gives some simple and interesting examples in relation to the role of invariance to theory, and comes to the conclusion that "a theory always amounts to the assumption that something remains constant." He is dealing with very elementary theories, but his observation is capable of generalization if

The discovery of invariant relations among various species of plants and animals has been of utmost significance in biology. Some historical aspects of this problem were discussed in the last chapter. In contrast to biology, failure to discover a basis of classification which would put psychological phenomena in some frame of invariant relations with respect to one another, has prevented psychology from becoming a science, notwithstanding the many claims of the psychoanalysis school to the contrary. It was seen that the rudimentary invariances exhibited in the original biological classificatory schemes, especially that of Linnaeus, were essential to the development of biology on theoretical fronts.

In economics the notion of invariance rooted in the directly observed (or observable) facts has not attracted much interest until recently. The internal logic of the partial equilibrium analysis, popularized by Marshall, tends to direct the economists' attention toward the highly unstable price-quantity relations in the market rather than the more stable patterns of resources, technology, and consumer tastes. This proposition will be examined in detail in section 6 of this chapter. It is convenient to approach the issue indirectly and at the same time taking into account some parallel

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appropriately modified. See Henri Theil, Applied Economic Forecasting, Amsterdam: North Holland Publishing Co., 1966, p. 2.

developments in the economic science.

Historically, it was recognized as early as the 1770's by Adam Smith that the component parts of the economic system continually responded to changes that occur in other parts in such a way that the original impetus will cease to call for further change. (The "invisible hand.") For example, the baker reacts to an increase in the price of bread--which may be due to increased demand--by producing more bread, coming to a new equilibrium quantity and price which will rule as long as all parts of the economic system exactly preserve their present states. Much elaboration has been introduced into this general proposition since Smith, though the proposition remains fundamentally the same. The analogy with a computing machine is suggestive:

The economy may be envisioned as a giant computer that continually solves a system of equations--these equations having been devised in such a way that they would reflect the fundamental properties of the economic system and relate the basic variables of the system to one another. The computing problem aside, the theory of general equilibrium developed by Leon Walras was precisely such a system of equations.

A sketch of Walras's system will be presented in order to give specific substance to the arguments that follow.[67]

Essentially Walras conceived of the economic system as the agglomeration of a large number of markets, each market being characterized by a pair of relations--supply and demand equations for the market specified. In mathematical terms:

$$(3.11) \qquad q_{di} = \sum_{j=1}^{n} d_{ij} p_j + F_{di} \qquad (i = 1, 2, \ldots, n)$$

where n denotes the number of markets (or commodities), q_{di} the amount of i-th commodity demanded, d_{ij} the "structural parameters" which specify the function, p_j price of the j-th commodity, and F_{di} the "non-economic" factors (such as tastes of consumers) that are treated as given in the model. For example consider $f_{d2} = 5p_1 - .3p_2 + 8$. Here the quantity demanded of this commodity depends on two prices p_1 and p_2 and the level of demand for the commodity is given by a "shift parameter" whose value is fixed at 8 in this example. This shift parameter could account for the effects of tastes, exports or imports of the commodity, etc. Thus if consumers' preferences change in favor of this commodity so that at the same prices consumers want more of it, the value of the shift

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[67]The formulation of Walras's system presented here closely follows that given by Shiou-Shuang Yan, Introduction to Input-Output Economics, New York: Holt, Rinehart, and Winston, 1969, pp. 30-35.

parameter shall be higher, say, 12 rather than 8.

The supply equation for commodity i may be written as

(3.12) $$q_{si} = \sum_{j=1}^{n} s_{ij}p_j + F_{si} \qquad (i = 1, 2, \ldots, n)$$

Let

(3.13)

$$p = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix}, \quad q_d = \begin{bmatrix} q_{d1} \\ q_{d2} \\ \vdots \\ q_{dn} \end{bmatrix}, \quad F_d = \begin{bmatrix} F_{d1} \\ F_{d2} \\ \vdots \\ F_{dn} \end{bmatrix}, \quad q_s = \begin{bmatrix} q_{s1} \\ q_{s2} \\ \vdots \\ q_{sn} \end{bmatrix} \quad F_s = \begin{bmatrix} F_{s1} \\ F_{s2} \\ \vdots \\ F_{sn} \end{bmatrix}$$

and

$$\begin{aligned} D &= [d_{ij}] \\ S &= [s_{ij}] \end{aligned} \qquad (i, j, = 1, 2, \ldots, n)$$

Then (3.11) and (3.12) can be written in vector and matrix form as follows:

(3.14) $$q_d = Dp + F_d$$

(3.15) $$q_s = Sp + F_s$$

The equilibrium in the system is attained when quantity supplied and demanded are equal in every one of the n markets specified. That is, when

(3.16) $$q_{di} = q_{si} \qquad (i = 1, 2, \ldots, n)$$

or in vector form

(3.17) $$q_d = q_s$$

From (3.14), (3.15), and (3.17) one can write

(3.18) $$Dp + F_d = Sp + F_s$$

or

(3.19) $$(D - S)p = F_s - F_d$$

Premultiply both sides of (3.19) by the inverse matrix $(D - S)^{-1}$ to get

(3.20) $$p = (D - S)^{-1} (F_s - F_d)$$

Substitute from (3.20) into (3.14) to get

(3.21) $$q_d = D(D - S)^{-1} (F_s - F_d) + F_d$$

Expressions (3.20) and (3.21) give the various prices and quantities in terms of the "structural matrix" matrices D and S, and "factors" F_s and F_d. A closer examination of the nature of the structural matrices and the "factors" are, therefore, appropriate.

First, notice that d_{ij} and s_{ij} are the parameters that, when numerically estimated, give a quantitative expression to the various demand and supply relations in the system. The quantitative determination of, say, d_{37} would measure the amount of change in quantity demanded of product 3 when the price of product 7 changes by one unit. In a nonlinear formulation of the model d_{ij} would not necessarily be a parameter; it may designate a variable. d_{37} may be positive, zero, or negative, depending on the nature of the interrelationship between the two products. Because d_{ij} and s_{ij} give the specification of the mode of interrelationships among the various products--that is, they show how the individual parts are tied together to constitute a whole--they are called "structural parameters." The invariance of these structural parameters is a point that must be examined closely. However, an overview of the Walrasian system as a whole is undertaken first.

Second, F_d consist essentially of psychological and sociological elements that enter the determination of consumers' tastes. These are considered to be "outside" the model. Their value is assumed to be independent of the variable vectors q_d and q_s of the model. More will be said of the invariance assumptions with respect to these factors later.

Finally, F_s represents "non-economic" factors of technology and of natural resources. More about these later.

It is, therefore, seen that the Walrasian system, assuming a given structure in the economic system, ultimately derives the unknown values of prices and quantities of various commodities from the <u>fundamental</u> data of technology, resources, and comsumers' tastes. This realization together with a direct recognition of interdependence of component parts of an economic system were the two great merits of the Walrasian system. The first showed that behind the surface of market operations lie the more fundamental elements of natural, technological, and socio-psychological character. It was shown that the immediately perceived relations rest on factors that are, in a sense, indirect and more remote.

The second important contribution of Walras was to give explicit recognition (and a formulation) to the notion of structure in an economic system.

A third aspect of this model may be mentioned; namely, its implications in terms of classificatory taxonomic work in economics. It showed that for the purpose of quantitative determination of economic quantities it is necessary to preserve in the model explicitly, avoiding aggregation, and averaging which bring about a superficial simplicity at the expense of quantitative indeterminancy. But the classificatory implications of the Walrasian system were of little operational significance. Specifically, the structural parameters of the system could not be observed and measured directly and the interrelationship of the classified items (commodities) were expressed not directly but through the intermediacy of the supply and demand relationships.

So long as the model is used only as a theoretical curiosity and no attempt is made towards the construction of a numerical analogue for it, it matters little whether its parameters are directly observable or not, or whether they are relatively stable or not. In fact, Walras and his follower Pareto thought of their general equilibrium scheme as a purely theoretical setup and thought that its empirical specification, even if possible, would result in a system of equations whose solution would be beyond all computing ability. They did not foresee the computing revolution that would occur in the third quarter of the twentieth century!

Thus, virtually no attention was paid to the notion of structural invariance, a property which must be expected to some limit on *a priori* grounds if the empirical implementation of the model is perceived. This is so because the determination of such a structure is of no value unless it is expected to remain relatively unchanged as some other components of the model change. A highly volatile structure is of no use for empirical prediction. Prediction always involves some element that stays constant.[68] The notion of invariance is essential to prediction just as ability to predict is the essential characteristic of an empirical theory. Therefore, the building of empirically significant theories involves a systematic search for various types of invariant relations among the variables of interest.[69] It will be seen that Leontief's model is built around such invariant

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[68] See footnote 66.

[69] That invariance is a relative not an absolute concept should become evident in the context as the discussion proceeds. An abstract analysis of the notion of invariance can easily degenerate into a barren

structures that can be numerically specified by direct observation.

A parallel development in economics occurred in a different direction: that of partial equilibrium analysis. Here an isolated sector of the economy, say a single industry or even a firm, constitutes the object of analysis. This approach heavily leans on the "simplifying" ceteris paribus assumption, according to which the external setting of the unit under analysis in its relationships to the rest of the economy are considered as given.

The Marshallian partial equilibrium analysis explicitly abstracts from the feature of interdependence among economic quantities and, because of this, does away with the notion of "structure" altogether. Yet the proponents of partial equilibrium analysis continue to refer to the economy as a system though a system is definable only by virtue of its component parts or structure. Reference to a system without specifying a structure for it is reference to no system at all.[70]

It may be claimed that the partial equilibrium approach is a pragmatic, tactical measure toward the strategic goal of numerical specification of the entire Walrasian system by taking the supply and

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exercise in formal logic.

[70]Webster's New World Dictionary defines the word "system" as follows: "a set or arrangement of things so related or connected as to form a unity or organic whole." "Structure" is defined as "the arrangement or interrelation of all the parts of a whole; manner or organization construction."

demand relations one by one. But "while waiting for the accumulation of the hundreds of empirical market behavior equations which ultimately would be combined to form a complete Walrasian system, one expected to be able to use the separate equations as they became available for the solutions of partial equilibrium problems."[71]

The characteristic common to both the Marshallian partial, and the Walrasian general, equilibrium systems is their preoccupation with the supply and demand relations in a direct way. An explanation given in terms of the market supply and demand functions were expected to be simpler--because they are more immediate--than that which would have required delving into the deeper layers of technology, tastes, and resources.

"As objects of empirical analysis the market supply and demand functions proved to be singularly elusive."[72] These relations cannot be observed directly. All that is observable is a pair of price-quantity values. The methods of indirect statistical inference--with a few notable exceptions--have failed to specify these functions. The principle difficulty is due to the volatile nature of the observed price-quantity relationships. Leontief advances an argument that such

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[71] W. Leontief, "Input-Output Analysis and General Equilibrium Theory," in Barna, p. 43.

[72] Ibid.

instability is inherent in the internal logic of the general equilibrium itself.[73]

Thus neither the partial, nor the general, equilibrium theories were able to direct empirical work towards the discovery of empirically invariant relations in the economic system.

The claim often made, in methodological criticisms of economics, that economists as a whole have wanted quick results and have refused to "dirty their hands" with facts is untenable. A review of the massive works of the Historical School in Europe and Wesley Mitchell in the United States should give an impression of the scope or empirical work in economics. Professor Leontief notes that "to Mitchell, to his pupils, and to his successors, this country owes the large-scale dev development of descriptive economic statistics, without which not only modern economics but many of the modern economic institutions could not possibly exist."

Both Wesley Mitchell and Historicism represented the anti-theoretical trend among some economists. This anti-theoretical sentiment was in time proven to be justified. This had to do with the emergence and development of econometrics.

Attempts at derivation of a "statistical demand curve" were

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[73] Ibid.

made as early as 1917 by H. Moore.[74] This was followed by many similar studies.

The "unsophisticated" phase of econometric work aimed at an indirect determination of the structural parameters of the system through statistical analysis of the behavior of its variables, reached its high point in the works of Henry Schultz, Paul Douglas, and Jan Tinbergan.[75]

It was characterized by rather careful collection and organization of primary statistical material and use of "least square" curve fitting techniques in calculation of the actual parameters. After fitting a curve to the data it was no simple matter to decide whether it represented the supply or the demand curve for the specified commodity or perhaps some weighted average of the two (the problem of identification).

"It was only natural to make the crudity of the statistical procedure used responsible for such disappointing substantive results. Far from being satisfied with the simple adaptation of recent advances in mathematical statistics, the new econometric school made a number of original contributions to the theory of stochastic systems

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[74]Henry Moore, Forecasting the Yield and Price of Cotton, New York: 1917, as quoted in Leontief, Essays . . . , p. 37.

[75]The following review of development in econometrics closely follows that given by Professor Leontief in his Essays . . . , pp. 37-38.

and the methodology of indirect statistical inference."[76] Among these was the development of the theory of identification.

But the positive contributions which these advanced statistical and mathematical methods were able to make toward actual empirical determination of the specific quantitative properties of the observed economic system proved to be quite limited, hardly greater than that made by the primitive methods used by studied belonging to the "unsophisticated phase" of the econometric movement.

According to Professor Leontief the explanation of this disappointing result lies in the fact that for a study of a set of quantitative interrelationships "as complex as those underlying a modern economy indirect statistical inference, however refined methodologically, simply will not do. Statistical reliability measures, if properly applied to even the most favorable situation--so far as primary information is concerned--yield confidence limits so far apart as to negate the empirical usefulness of the numerical parameters obtained."[77]

The above statements should not impart the impression that this author discounts the immesurable contributions of econometrics to the advancement of economic science. In particular, the

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[76] Ibid., p. 37.

[77] Ibid., p. 38.

contributions of econometrics in the precise formulation of many economic concepts, which were at first ambiguous and had to be precisely defined before they were quantitatively specified, is of utmost significance. This author believes, however, that together with the advancement of the method of econometrics it is necessary to reorient economic theory in the direction of empirical verification. That is, the economic theorist must be asked to meet the econometrician half way. Theories must be required to complete in the sense that not only the relations between variables but also variables themselves be defined in specific terms. For example instead of "money" one should indicate demand deposits plus currency and coin or whatever definition the theorists had in mind. Further, the theorists should consider the observability and, therefore, the empirical measurability of the relations he formulates.

Thus it became evident that the market relations of supply and demand, in spite of their immediacy, could not assume a focal position in empirical economics because (1) themethod of indirect inference could not, in general, empirically derive the shape of these functions, and (2) even if this could be achieved, the resulting information would be of little value because of the inherent instability of the market supply and demand relations.

It seemed natural, therefore, to bypass the market and approach the structure of the economy directly at the root, dealing with resources, technology, and taste without going through the intermediacy of the market.

This direct approach developed in two directions independently: (1) Input-output analysis, with its root in classical economics--the tableau economique of Quesnay. (2) The linear programming school developed basically by Kantorovich in Russia and Dantzig in the United States.

Both these approaches made the technological structure of the productive unit under analysis the focal point of empirical work. Linear programming has already been introduced and input-output analysis will be explored extensively in the following chapters. Suffice it to say that both systems aspire towards a classificatory scheme which would be based, as far as possible, on the notion of process (or activity), with process being an entity which is completely specified by its inputs and outputs. Linear programming has followed this approach in practice. This is possible because the technique has, up until recently, been applied mostly to such productive units as an establishment, a firm, or even departments within these units. Therefore, the number of processes involved has been manageable relative to the existing computing capacities.

In the case of input-output analysis, however, the economy as a whole has usually been the object of analysis. In order to reduce the model to a manageable size, it has been necessary to do a considerable amount of aggregation. Nor has the limitation of the existing computing facilities been the only factor necessitating such aggregation. The development of input-output has up to now relied essentially on the statistical material already available. Yet much new information is needed in order to better approximate the theoretical requirements of the input-output model. These problems will be investigated in great detail in the ensuing chapters. Here, a general introduction will be presented in order to elucidate the nature of problems involved.

The emergence of the notion of activity (or process) in such independently developed areas as linear programming, input-output analysis, game theory, and the von Neumann model is by no means an accidental event. Rather it is the well-defined character, quantifiability, and relative-stability-over-time, of the entity defined as a "process" that has made it such a fundamental concept in so many distinct areas of empirical economics. Note that the existence of technological progress in no way contradicts the stability referred to here. Firstly, a great many processes are repeated year after year. Many others are modified from one period to next. New ones are introduced and some old ones are abandoned. However, as mentioned elsewhere in the study, many modifications of the old processes or introduction of new ones are actually put to work sometimes after they have been invented. This is so because it takes time to study all the various aspects--technological, market, etc.,--of the utilization of the new processes: obsoletion of older equipments, retraining of labor, the cost of "learning" to operate with the new process present, these are some of the features that cause a lag between the invention and actual use of a process. Thus, changes in the set of processes that constitute the technology of an economy are, in principle, predictable.

So fundamental is the concept that it oversteps the institutional boundaries of such different economic systems as those of the Soviet Union and the United States.

A process is, indeed, an <u>elementary order</u> in the sense discussed in the early part of this chapter. It is similar to a thing in the sense that it constitutes a <u>constant conjunction</u> of a set of properties. In fact a process is defined much more rigorously as an empirical entity than a "thing." The properties that appear in an invariant association together in a process are nothing but the set of quantity-specific commodities that completely specify the process. Thus a process is defined in terms of exact quantities of (qualitatively) distinct goods as inputs and as opposed to the concept of "thing" that refers to an invariant conjunction of properties without necessarily expressing quantitative specifications among the properties involved.

It it is true, as Cohen holds, that the recognition of the "elementary order" embodied in "things" is an essential step toward the recognition of more complex "orders" such as causal order or order expressed in comprehensive theories, then it must be true that a full recognition of the concept of "process" as defined above, is a prerequisite for more involved theories about the parts or the whole of an economic system. Unfortunately, the notion has not been assimilated into economic literature as one might have expected early after its introduction by von Neumann, Dantzig, and others. One possible reason for this is the tremendous momentum that economic theory has gained over the years. As a self-feeding world of thought, impressed with its monumental logical skeleton and "aesthetic charms,"[78] economic theory has little use for concepts evolving in such "remotely related" (?) fields as Operations Research, industrial engineering, etc. Further, existing economic theory is characterized by its aggregative, typicalistic, and non-linear features. (These will be discussed in the following section.)[79] All three of these features are fundamentally in opposition to the concept of process, for, as it has been seen in several different contexts, the notion of process is the elementary building block of highly disaggregated models of linear structures. As to the typicalism of

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[78] See Robinson, p. 3.

[79] On the role of non-linearity see sections 2.A and 3, Chapter V.

economic theory, the concept of process is a "populationist," as opposed to typicalistic, one[80] (borrowing this term from biology), that is, it is empirically arrived at by direct measurement from the "population" (in the statistical sense of the word) itself. It is not a measure of typicality. This argument will be clear when in the following section the meaning of typicalism in economic theory is spelled out.

7. Some Philosophical Barriers in Economic Science

In the preceding chapter it was pointed out that biology had to rid itself of some philosophical conceptions (and adopt new ones) before it could emerge as an empirical science. In particular, "performism,""typological thinking," and "reductionism" constituted three distinct philosophical orientations that continually tended to push the science into narrow channels of preconceived notions alien to the qualitative differentiation actually observed. The problem was essentially that of attempting to superimpose extra-empirical notions upon the observed reality.

Some such tendencies can be detected in economics. Here, it manifests itself in the extra-empirical trends of "theoretical typicalism," "theoretical aggregationism," and methodological idealism. The latter is studied in a separate section under the title

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[80] See section 2. D. i, Chapter II.

of "cult of ideality." The former two will be studied here.

Theoretical typicalism is the analytical offspring of methodological idealism. The Marshallian "representative" (or "typical") firm is the best exemplification of theoretical typicalism in economics. It differs from empirical typicalism in that the latter always refers to a well-defined statistical measure of central tendency, with explicit reference to a statistical population some of whose characteristics are known. For example, the mode of a population--the most frequently occurring event in it--is usually used as a measure of "typicalness." Other usual measures are mean and median. However, in the absence of other specifications with regard to a given population it is impossible to decide which of these three measures can best be regarded as a "representative" event in the population. Knowledge of variability in the population is an indispensable information for such a decision. Indeed, it may be the case that none of these measures can meaningfully represent the population. This will be the case when variability in the population is large. Therefore, the notion of "typical," which appears to be quite clear to "common sense," becomes one that may be meaningless under certain circumstances or one that can mean any of three distinct statistical measures of central tendency, under certain other circumstances. The notation is far from being operationally rigorous: there is no one-to-one correspondence between it and some empirical measure.

The notion of "type" in analytical work has, so to speak, "a higher power of vagueness" than that involved in statistical (or empirical) typicalism. This is so for several reasons:

First, statistical populations, in so far as the notion of "type" is concerned, consist of occurrences of events which are nothing but measurement of a specific qualitative characteristic of an empirical population. Thus measurement of height of male students in a given university results in a statistical population. Therefore, the "population" can be represented along a one-dimensional extension that is graduated (or quantified) according to the measurements made or expected. The characteristic under study is well-defined and obtainable by direct observation and measurement (or counting).

Theoretical types, however, usually involve several elementary notions few of which, if any, are well-defined empirically. In the case of the Marshallian typical firm, for example, the notions of price, output, marginal cost, and average cost enter as elementary concepts. Some of these concepts will be examined:

If the firm is "typical" of the industry, it follows that it has a typical marginal cost, typical average cost, typical market demand, and a typical output. Everything that was said above about the notion of "typicalness" in statistics is also true with regard to these "typical" analytic constructs. But there are, of course, additional problems here. Take, for instance, the simplest one--"typical output."

What is the typical output of a firm: Is it the principal output the firm markets? Is it an index of several products? How should an insistent empiricist go about measuring the typical output of a firm?

If the principal output is treated as the typical one then the other (several) outputs of the firm must be assigned to those firms whose principal outputs consist of these commodities. But this would imply a classification on commodity basis not on decision-unit basis (which, for convenience, will be called functional basis in this study). Since the purpose of the analytical construct, "the typical firm," is to show the outcome of decision of entrepreneurs as a determinant of output, it follows that "output" must refer not to a part--the principal output--of the firm but to the whole output.[81]

It may be suggested that the firm will optimize its decision with respect to each distinct output it produces. That is, the firm will produce that output of each commodity in its product line that

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[81]Even the much less aggregative unit, establishment, does not eliminate the problem of lack of homogeneity of output, for many establishments produce several different products and occasionally change from one "primary product" to another. See "Introduct," Census of Manufactures, 1964.

would equate the price of that product to its marginal cost. In symbols where P_i and MC_i are the price and marginal cost of

$$P_i = MC_i \qquad (i = 1, 2, \ldots, n)$$

product i and n is the number of products that the firm produces.

This line of reasoning presupposes the possibility of separating the various cost items and classifying them according to the type of product. In a multi-product, integrated organization, however, such a classification becomes an almost impossible empirical task. The main problem is that of joint costs--the type of costs that are simultaneously involved in the production, accumulation, or warehousing of two or more products. The problem of allocating such joint costs to the various products involved is often a very difficult task and may involve purely arbitrary or rule-of-thumb methods.[82]

The extent to which the occurrence of such joint costs interferences with a meaningful classification of costs--one that involves mutually exclusive and collectively exhaustive classes[83]--cannot be settled on a priori grounds. Only an empirical investigation of the

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[82]See Elwood S. Buffa, Operations Management: Problems and Models, 2nd ed.; New York: John Wiley and Sons, Inc., 1968, p. 23.

[83]The word "dichotomy" is used to mean "division into two parts." In logic it means division of a class into two opposed subclasses, as real and unreal. It will be used in this study in both senses depending on the context in which it appears.

problem can provide a final answer to it. However, it may be said that as the multi-product, integrated firm becomes more prevalent as a basic productive organization in the economy the importance of joint costs relative to total costs increases and to that extent the optimization rule $P_i = MC_i$ becomes less determinate empirically.

It may be said that, rather than treating the product "basket" of the firm as consisting of a number of qualitatively different products with different prices, it is possible to construct an index of output and price, thereby reducing the optimization problem to that of $P = MC$ where P and MC are indexes of price and marginal cost, respectively. But this is not acceptable because of all the familiar index number problems, too well-known to be repeated here. Further, the index-number approach would betray the "precision" of the "adjustment at the margin" which is implied by the marginal analysis. It is paradoxical that economic theory insists on marginalism just as the economic empiricism emphasizes indec construction. This paradox is perhaps the most outstanding manifestation of the utter separation of economics into two independent fields of inquiry: theoretical and empirical. This paradox gives a specific instance of what will be called "the fundamental dichotomy in economics." This dichotomy refers to the compartmentalization of theoretical and empirical works into two separate--though methodologically inseparable--spheres of investigation. That these two spheres are inseparable in empirical sciences was the main theme of the preceding chapter. That the two are actually separated in economics is an undeniable statment that can be substantiated by even a most casual survey of the science. References to this point will be found throughout this study. That disaggregation of theoretical concepts and classification of empirical facts are the unavoidable links between these two spheres of economic inquiry, constitutes a central theme of this study. That theoretical disaggregation of concepts and empirical classification of facts cannot proceed independently and must interact constantly, is a major finding of this study. But this is leading away from the specific questions posed in this section.

Returning to the notion of "typical firm," it was seen that the "elementary concepts" of price, output, and marginal cost are not free from ambiguity in the case of a specific firm. Distinguishing between the various products of the firm would shift the problem "backward" to the cost side, posing the difficulties of allocating joint costs. On the other hand ignoring the distinction between the various products through the construction of indexes of output, price, and cost would betray the very logic of marginalism. Thus the firm, this fundamental unit of Marshallian analysis is devoid of empirical significance. There are other angles for looking at this problem. In a separate section it will be seen that the choice of a firm as an elementary unit of analysis is the outcome of a much more fundamental tendency in the economic science: reduction of economics to praxiology a la Marshall, von Mises, Robins, and others.[84]

Even if the elementary concepts that are involved in the notion of typical firm were not problematic in the sense of being empirically vague and methodoligically inefficient, the purely statistical problems of representing an industry by a typical firm

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[84]Such hasty conclusions are justified only on the assumption that the reader is familiar with the issues at hand. Otherwise, a lengthy discussion and documentation would push this study beyond its predesignated limits and change its nature as well. Few comments as to the direction of future work may be appropriate: This writer is convinced that the various developments during the past three decades in economics have prepared the ground for an all-out attack on Marshallianism and all its ramifications. The strategic lines of such a plan are not difficult to depict. The battle would have to be fought on four distinct but interrelated fronts: (1) General equilibrium would replace partial reuilibrium, perhaps completely eliminating the micro-macro dichotomy along the lines suggested by Leontief, von Neumann, etc. (2) Decision making and praxiological theorems would be put in their proper relation to the economic science, ruling out the tendencies of reducing the science to praxiology. (3) Theoretical aggregationism a la Keynes, Kahn, etc., would be reduced to a minimal level, opening room for models of theoretically disaggregated character. (4) Econometrics would be reoriented from its emphasis of indirect observation and inference--the empirical counterpart of aggregationism in the formulation of the theoretical models--to that of direct observation against the background of a theoretically disaggregated model, with indirect inference playing a supplementary role.

All four of the above lines of inquiry should be embedded in a general philosophical frame with full considerations given to metaphysical, epistomological, and logical aspects of the economic science. Much of the discussions about the methodological problems of economics seem to be limited to the sphere of logic. This would invalidate the approach beyond all usefulness.

The notion of type in statistics involved a reasonably symmetrical distribution with significant concentration of the elements of the population around some measure of central tendency which is used as a "measure of typicalness." How many industries in the United States economy are characterized by such a distribution of firms[85] around the "typical firm"? Though this question can be settled only through empirical research, it can be said that many industries are likely to have a large number of small size units, with few intermediate and fewer large size units. If this were the case--and there is no reason to reject this in favor of the Marshallian assumption a priori--it follows that the distribution of firms, far from being symmetrical, is of a hyperbolic form, leaving no room for inferences that involve the notion of "typical."

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cannot possibly be sufficient for the purpose at hand. The present study is a miniature, embryonic form of such an ambitious plan. Such a comprehensive reexamination of a science is no child's play, no task of few months or even few years. It demands a lifetime of dedicated scholarship.

[85]It should be pointed out that finding a characteristic that would be used as a common denominator of comparison is no easy matter. Marshall conceives of his theoretical industry as consisting of so many firms of equal size with similar cost structures. Any attempt to translate this abstract industry into an empirical entity would only reveal the ephemeral and elusive nature of the abstraction involved.

Thus not only the notion of "typical firm" but also the very concept of "industry" in the Marshallian sense is open to serious questions.

All the above ambiguities and statistical difficulties lead to the lowering of analytic efficiency in economics to the level of purely qualitative results, at best indicating only direction of change in some magnitudes (with no specification of the extent of change involved), and at worst giving qualitatively indeterminate results; quantitative indeterminacy always being present. It may be said, therefore, that one analytic outcome of theoretical typicalism as a methodological approach is quantitative indeterminacy.

But there are other aspects of the prevailing methodology in economics that lead to quantitative indeterminacy also. Theoretical aggregationism is one such factor.

Theoretical aggregationism is a tendency toward formulating economic problems in terms of few broad aggregates. It is present on both micro and macro levels. The implied overall production function for the Marshallian firm, the overall production function for the "Keynesian" general equilibrium models,[86] the overall Keynesian consumption function, and in fact every fundamental "schedule" in macro, and many of those in microanalysis, are examples of this tendency in economics.

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[86]See section 3, Chapter V.

In case of certain aggregate such as the consumption function a certain degree of stability is manifested in spite of the volatile nature of many of its components. The importance of stability of economic relations has already been studied in this chapter in the sections on invariance. The statistical specification of the consumption function is undoubtedly a very useful and important undertaking in economics. But what is an even more useful and important task is a multi-dimensional disaggregation of the function along such lines (dimensions) as the type of product consumed, class of consumers, and region (location) of consumers. It is very likely that changes in the short-run behavior of the consumption function can be understood through a detailed knowledge of the degree of volatility (or stability) as well as a knowledge of trends in the components.

In the case of many other aggregates of macroeconomics the long-run stability present in the consumption function is absent. Here the aggregates reflect the interaction of so many varieties of factors that it is impossible to have a meaningful statistical estimation of the relationships involved. The Keynesian "marginal efficiency of capital" is such a schedule. So is the "liquidity preference" schedule and many others. The basic problem involved in theoretical aggregationism is well articulated by Leontief who writes:

> [the aggregative approach] always leads us from the nearly unlimited diversity of the immediately observed world into the simplified realm of aggregative magnitides

> which can be described and analyzed with greater ease since the number of distinct variables in it is relatively small. The way leading from one into the other world is, however, a one-way route. We cannot pass from the aggregative concept to the economic phenomena as they have been directly observed any more than we can turn an omelette into the whole eggs from which it has been made. This is why the economic analysis in its most aggregative, but because of that also most systematic and easily manageable, form carries with it a faint but unmistakable air of unreality.[87]

Aggregation necessitates the suppression of qualitative differences. For example, a series that indicates the productivity of the transportation industry increased 400 per cent from 1865 to 1965 ignores the differences between horse-drawn carriage, the railroad of 1865, the car and the airplane of 1965. Within the framework of a reasonably disaggregated analytical scheme a comparison of the total number of transportation vehicles produced in the years 1865 and 1965 makes little sense. Neither is such a comparison required for an explanation of the developmental process extended over the long period of time comprising both these years.[88]

Economic empiricism begins with the vast qualitative differentiation that is immediately observed in reality. For economic theory to come closer to the empirically observed world it is necessary to open room for more qualitative differences in the formulation of the

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[87] Leontief, Essays . . . , pp. 18-19.

[88] This example is due to Leontief, Essays . . . , pp. 18-19.

theoretical models. Leontief notes that:

> The unreality of the aggregative approach can be reduced only through the use of less aggregative models. An analytical system which permits us to distinguish horse-carriages from cars and cars from airplanes can obviously maintain a closer, less equivocal relationship to the observed facts than a system that leaves no room for such qualitative distinctions.[89]

In the absence of more theoretically disaggregated models the economic empiricists, faced with the problem of "introducing some order" into the vast amounts of facts they collect, proceed to develop their own "methods of analysis." Leontief writes in this connection that:

> . . . far from seeking to establish a close--not to say intimate--co-operation with the theorist, many of the empirically minded investigators came to consider direct observation as a separate, self-sufficient approach to the explanation of the functioning of the economic system rather than the necessary descriptive complement of its theoretical analysis.
>
> The empirical school developed even a kind of quantitative descriptive technique all its own. Its principal or rather only tools are averaging and aggregation. . . . While the theorist discovers or, should I say introduces order into the complex multiplicity of measurable economic phenomena by reducing it to a system of equations, the radical empiricist simplifies the quantitative picture by describing it in terms of few broad aggregates and averages. A detailed tabulation of the amounts of all the many kinds of goods and services consumed in the course of a given year by households or invested in all the various industries. . . is replaced, for example, by one single figure identified as *the* annual Net National Income.[90]

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[89] *Ibid.*, p. 19.

[90] *Ibid.*, p. 39.

Here, then, is another side of the "fundamental dichotomy" referred to above. This time the dichotomy manifests itself in the appearance of <u>empirical methods and theoretical methods independent of one another.</u> Aggregationism is seen to be prevalent not only on the theoretical side but also in the sphere of empirical works as well. Thus the methodological symptom so far referred to as "theoretical aggregationism" may be modified as "theoretico-empirical aggregationism." Yet the adjective "theoretico-empirical" should not in any way imply any dependence between the two types of aggregation involved. It was seen above that the two developed independently by separate investigators. In fact aggregationism as an approach is the cause as well as the result of the "fundamental dichotomy" in economics. Only neglect of the immense variety in the observed world can lead to the highly aggregative formulations of economic theory. On the other hand only contempt for theory induces the economic empiricist to limit its conceptual constructs to simple (or weighted) aggregations or averages.

The analytical outcome of theoretical aggregationism is quantitative indeterminacy of economic quantities and relationships, just as the analytical outcome of empirical aggregationism is lack of any analysis on the one hand and supporesion of all detains embodied in facts (or qualitative indeterminacy), on the other hand.

Thus "theoretical typicalism," "theoretico-empirical aggregationism," and radical empiricism are some of the philosophical footholds that must be abandoned if economics is to make progress as an empirical science. These tendencies can be shown to reduce to metaphysical, extra-scientific notions either through the path of rationalism to philosophical idealism *a la* Hegel and Berkeley, or to mechanistic materialism *a la* Democritus and certain extremist sects within the school of British empiricism. This philosophical line of generalization shall not be followed further here due to scope considerations.

8. On Praxiological Subjectivism in Economics

Lange defines the *economic principle* or the *principle of economic rationality* as a "general principle of procedure when the ends and means of activity are quantified."[91] This principle asserts that the maximum degree of realization of the end is achieved by proceeding in such a way that either for a given outlay of means the maximum degree of realization of the end the outlay of the means is minimal.[92]

Economic rationality--that is, economic activity according to

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[91] Lange, p. 167.

[92] Lange modifies the above definition: "Strictly speaking, the full quantification of the end of activity is not necessary for the application of the economic principle. It is sufficient if the degrees of realization of the end form an ordered set so that it is possible to say whether the end is achieved in a greater or lesser degree." *Ibid.*

rules of reason--evolved historically, replacing economic traditionality. It becamd a dominant feature in those societies where commodity production and commodity-money-commodity circulation developed into the main vehicle of economic activity. In the natural (or traditional) economy production and distribution are devoted to the direct satisfaction of needs, the stimuli determining the aims of economic activity being concrete needs. The multiplicity of concrete needs (e.g. food, clothing, shelter, and weapons) implies correspondingly diverse aims of economic activity. The needs (and therefore the aims) in a natural economy existed and changed within a determinate set of conditions of human social life, which is called the culture of the given society. Tradition played a major role in the specification of these needs; hence, the expression "traditional economy."[93]

The rise of market economy leads to the condition whereby money income becomes an economic necessity, the key end--one whose realization is a precondition for the realization of all other aims. Hence, needs (and therefore aims) are no more of a concrete character but they resolve into the single objective of acquiring commodity in general--general purchasing power. This tended to undermine the traditional set of aims of the natural economy.

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[93]For a thorough discussion of the concept of natural or traditional activity see Ibid., pp. 150-153.

In a way this meant a simplification of economic activity for the multiplicity of aims--characteristic of the natural economy--was replaced by the singularity of aims. As Lange puts it this amounted to "an integration of means by a common end."[94] He writes that:

> In natural economy there are a great variety of parallel ends and an equally great variety of means; some means are specifically applied to particular ends (e.g., bread for food), others may serve various ends (e.g., wood for building houses, making carts, building bridges, or for fuel). This complicated system of ends and means is established by tradition and becomes the object of traditional and customary economic activity. On the other hand, the fact that in gainful activity there is only one end, that this end is unconditionally necessary and that all means are subordinated to this one end, simplifies activity, making it easy to analyze.[95]

With the development of the market economy and the emergence of uniform units of measurement--monetary units--it became possible to quantify ends and means. The quantitative measurability and commensurability of the ends and means--which lead to the emergence of the category of profit--made a complete rationalization of the activities of a productive enterprise possible. This was a giant stride in the development of human control over nature. The triumph of the principle of economic rationality was a consequence of the development of commodity production which in turn followed side by side with the process of social division of labor. However, once economic rationality

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[94] Ibid., p. 157.

[95] Ibid.

reached a certain stage of development it ceased to be a mere consequence of the process of division of labor. Indeed, it evolved into the position of a preconditioned for further progress in division of labor and technological development in general. This is another instance of feedback (or loop) in nature: the conclusion is transformed into a premise and vice versa; the logic of nature, and in this case, of evolution in nature, follows its own laws which may be at variance with the laws of logic of human mind. No wonder that pure logic cannot reveal the laws of nature; science tests its theories against facts.

Although classical economists were aware of the significance of the economic principle they did not identify the science of political economy with the application of the principle. Smith conceived of the science as the study of "wealth of nations"[96] and Ricardo was concerned with the "laws which regulate the distribution" of the total product among the various social classes.[97] Gradually more recognition was given to the principle of economic rationality. The development of utilitatianism opened the way for generalizing the economic principle to include, in addition to gainful activities measurable in terms of money income, subjective satisfaction. The subjective trend in economics best exemplified by the works of the Australian School put the

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[96] Joseph A. Schumpeter, History of Economic Analysis, New York: Oxford University Press, 1961, pp. 185-194.

[97] Ibid., p. 568.

market and consumer activity at the very heart of economic analysis, leaving the production side essentially out of the picture.[98] The ground was prepared for the reduction of economics to a branch of praxiology.

Praxiology may be defined as "the science of rational activity."[99] Its origin lies in the formulation of the economic principle by the classical economists. As was said in the preceding paragraphs the principle of economic rationality evolved with man's economic activity. Its application is not, however, limited to economic activity. "The economic principle is applied in many other spheres of human activity, above all in technology."[100] Also in military strategy and tactics the principle is operative. "Rational strategy or tactics consists in obtaining the maximum strategic or tactical effect

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[98] On the rise and development of economic subjectivism see Lange, pp. 160-207, and 226-278; also see Schumpeter, pp. 887, 1056-1057.

[99] Lange, p. 188.

[100] Ibid., p. 186. Lange gives this example: "The amount of work done by an engine may vary for a given amount of fuel or, what is the same thing, the amount of fuel used by an engine may vary for the performance of a given amount of work. We speak of a greater or lesser technical efficiency of the engine. When designing an engine we design one of the greatest possible technical efficiency for a particular cost of construction. Similarly in planning a power station, we endeavor to obtain the greatest technical efficiency, measured, say, in terms of the number of kilowatts of electric energy produced per ton of coal used, for particular costs of construction. This is procedure according to the economic principle."

with a given number of forces or [alternatively]. . . in obtaining a particular strategic or tactical effect with the minimum number of forces."[101]

Other examples of rational activity are: the rational method of teaching the piano which is that method by which the pupil makes the most progress in a given time (or a given amount of progress in the minimum amount of time); the rational method of transporting loads is that by which a given load is transported with the minimum of effort or by which the maximum load is transported for a given effort. The economic principle also finds application in scientific research. It appears most clearly in mathematical statistics when a certain parameter is to be estimated or a statistical hypothesis has to be verified on the basis of the smallest possible number of observations; well-known in this connection is the concept of the efficiency of various statistical methods.[102]

It is, therefore, seen that the economic principle, though finding its widest field of application in economic activity, where the principle appeared first, is by no means limited to this sphere alone. "Wherever activity is rational and the end is quantitatively measurable, or at least can be expressed in the form of greater or lesser

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[101] _Ibid._, p. 187.

[102] _Ibid._

degree of realization, there the economic principle is at work."[103] The principle of economic rationality is expected to embrace an ever greater area of human activity as more and more such activities are subjected to the critical reasoning of the scientifically-trained minds.

Since rationality of action characterizes many fields of human activity and not merely economic activity, there has developed a discipline which is concerned with what is common to all fields of rational activity--praxiology. "Praxiology may be described as the logic of rational activity. For it deals with methods of inference employed in rational activity. It formulates the general concepts which arise from rational activity. These are concepts like end and means, method, action, plan, effectiveness, economy, and so on."[104] These concepts are called praxiological categories. Praxiology establishes relations between praxiological categories which are called praxiological principles of behavior.[105] "The economic principle . . . is precisely one of these praxiological principles of behavior."[106]

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[103] Ibid.

[104] Ibid., p. 189.

[105] For some references to works in the field of praxiology see Lange, footnotes on pp. 189, 239, and 240.

[106] Ibid., p. 190.

The economic principle was given a central position by the subjectivist school. Jevons wrote that "pleasure and pain are undoubtedly the ultimate objects of the Calculus of Economics. To satisfy our wants with the least effort . . . , to maximize pleasure, is the problem of economics."[107] This exemplifies the hedonistic interpretation of the subjectionistic school with its origin in the utilitarian psychology. It appears, in addition to Jevons, in the works of Menger, Bohm-Bawerk, and Marshall.[108] This interpretation has, more recently, yielded to what may be called praxiological interpretation. This conceives utility as a degree of realization of the aim of economic activity, independent of the nature of the aim. "Whether it is the question of pleasure in psychological sense, or of money income, or of political power . . . --is a matter of indifference."[109] In recent economic writings the term "preference" has come to replace "utility." In this praxiological interpretation, the subjectivist trend leaves aside all psychological considerations and transforms itself into "a logic of rational choice aimed at the maximization of preference."[110]

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[107] W. S. Jevons, The Theory of Political Economy, 3rd ed.; London: 1888, p. 37, as quoted in Ibid., p. 233.

[108] See Lange, pp. 234-236 for more details on this school.

[109] Ibid., p. 235.

[110] For a concise history of development of the praxiological interpretation of utility since Pareto see Ibid., footnote on p. 236.

This interpretation was given its most consistent formulation in the hands of Robins,[111] von Mises,[112] and R. G. D. Allen and Hicks.[113]

According to Robins, "economics is the science which studies human behavior as a relationship between ends and scarce means which have alternative uses. . . . It [i.e., economics] does not attempt to pick out certain kinds of behavior, but focuses attention on a particular aspect of behavior, the form imposed by the influence of scarcity.[114] Thus economic science is conceived of as being concerned with certain aspects of human activity not with a particular field of this activity. As Lange notes: "Economic science understood in this way is a general study of behavior governed by the economic principle, a study which has an application in all fields of human behavior in which the economic principle applies."[115] Lange shows that this approach to the science amounts to transforming it into a branch of praxiology:

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[111]L. Robins, An Essay on the Nature and Significance of Economic Science, 2nd ed.; London, 1946.

[112]Ludwig von Mises, Human Action: A Treatise on Economics, New Haven, 1949.

[113]R. G. D. Allen and J. R. Hicks, " A Reconsideration of the Theory of Value," Economica, October, 1954.

[114]Robins, as quoted in Lange, pp. 237-238.

[115]Lange, p. 338.

> According to Robins the economic aspect of human activity consists in the fact that since the limited amount of means available can be applied in a variety of ways it is necessary to choose the ends for the realization of which these scarce means are to be used. A choice of this kind, however, assumes that there is a hierarchic structure of ends, that some ends are more important than others. Without a hierarchy of this kind it is impossible to make a rational choice of ends; on the other hand, the fact that a hierarchy of aims exists, presupposes that particular aims are the means to the realization of one principal end. In this case the choice of ends according to their relative importance is equivalent to the maximization of the principal end, i.e., proceeding according to the economic principle. Economic science is thus the science of the use of scarce means guaranteeing the maximum degree of realization of a chosen end of human activity.[116]

Hence, economics is reduced to a science of programming--a branch of praxiology. Von Mises explicitly announces this result.[117] The unavoidable consequence of this result is that economics ceases to be an empirical science concerned with objective phenomena. It is transformed into a formal "logic of choice" in which the only criterion of truth is the agreement of theorems with the axioms adopted.[118]

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[116] Ibid., pp. 238-239.

[117] "Out of the political economy of the classical school," writes von Mises, "emerges the general theory of human action. . . . No threatment of economic problem proper can avoid starting from acts of choice; economics becomes a part, although hitherto the best elaborated part, of a more universal science, praxiology." Von Mises, as quoted in Ibid., p. 239.

[118] Lange, p, 239.

Economic subjectivists went as far as stating that "economic science praxiologically conceived is knowledge of the laws of actual human activity *a priori*."[119]

To what extent the praxiological conception of economics is prevalent today can be detected from the very popular text on "Principles of Economics" by Professor Samuelson. He offers the following definitions:

> Economics is the study of how men and society *choose*, with or without the use of money, to employ *scarce* productive resources to provide various commodities over time and distribute them for consumption, now and in future, among various people and groups in society.[120] (Samuelson's emphasis.)

Thus economics is, according to Professor Samuelson, the study of *choice*--a particular aspect of human behavior--under conditions of *scarcity* of means. The problems of investment, capital structure, division of labor, and other considerations in relation to capital are supposedly taken care of by the phrase "now and in future" in the definition. No mention is made of technology as a definitely given state of human knowledge except that "how men . . . choose . . . to employ . . . resources . . . " implies that some technology prevails.

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[119] *Ibid.*, p. 240.

[120] Paul A. Samuelson, *Economics: An Introductory Analysis*, 5th ed.; New York: McGraw-Hill Book Co., Inc., 1961, p. 6.

Thus the study of the nature and availability of resources. the evolutionary character of the technological process and division of labor, the objectively existing "structure of the economy" (in the Leontief's or von Neumann's sense), the way in which these factors influence human choice--these and many other problems which were regarded as lying within the domain of economics by the classicists are left out. The objectively observable parts are announced as unimportant and the subjective element of choice is regarded as the only useful element in the overall activity of men that is important for theoretical economics.

It would be futile to pretend that Professor Samuelson's definition can be fully analyzed to the point of exposing its praxiologico-subjectivistic and anti-empirical nature in this brief section. Such a task would require a many-sided exposition of subjectivism rather than a sketchy reference such as the one presented here; it would inevitably lead into a critical examination of the "time-preference" theories of capital a la Bohm-Bawerk, Menger, and Fisher. Such an undertaking is beyond the scope of the present study. Thus the discussion will proceed along more specific lines in the direction of the fundamental theme of this study; namely, the problem of classification; while at the same time remembering that the analysis will of necessity be limited and preliminary in character.

That it is possible to abstract from the problem of optimization in economics--that is to abstract from the praxiological aspect of the science--without abandoning the science itself is fully demonstrated by the Leontief statis input-output model. In this model Leontief completely abstracts from the problem of choice in the economic science. On the production side a single technique is assumed to be actually applied by the producers.[121] On the consumers' side the composition of demand is treated as datum (in the open model). In other words, the Leontief model shows that it is possible to abandon praxiology without at the same time abandoning economics. The testimony to the significance of Leontief's model does not necessarily come from the quarters of its sympathizers. Professor Friedman, while expressing some reservations as to the usefulness of Leontief's model as a predictive device, writes that:

> The table is clearly an extremely useful and ingenious construction that can be regarded as a natural extension of the national income accounts.[122] As such, its value and usefulness are largely independent of the success of input-output analysis as a predictive technique. Any dispute about the table is only whether it is worth its cost, not whether it is worth having at all.[123]

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[121] See section 1, Chapter VI.

[122] In Chapter III of this study it is shown that both input-output and national income accounts can be embedded into a more general framework of national accounting. It is shown there, also, that whether one treats input-output as an extension of the national accounts or vice versa, is purely a matter of choice.

[123] Friedman, "Comment," Input-Output Analysis: An

As to the analytical usefulness of the model and its significance in relation to various specific problems of economics, Chapter VII of this study gives a selective overview of the area. It is concluded there that not only input-output analysis provides a more efficient, systematic, and informationally superior method of attacking the specific economic problems posed and attacked by the conventional aggregative (Keynesian) models, but also it provides tools for such problems that cannot even arise within the more aggregative frameworks. It is ironic, indeed, that the model that has abstracted from the problem of choice--that is, one that has abandoned the very core of the praxiologico-subjectivistic approach--is the one that has proved most fruitful and has won more widespread approval[124] than any other in economics. This is, of course, not accidental. It is, rather, a consistent and deliberate insistence on the methodological view that economics is an empirical science, that certain <u>observable invariant</u> relationships (such as that exhibited by the input-output table) can serve as a basis for theoretical generalization, that <u>the problem of</u>

<u>Appraisal</u>, National Bureau of Economic Research, Conference on Research in Income and Wealth, Princeton, New Jersey: Princeton University Press, 1955, p. 170.

[124] As early as 1959 more than 20 different countries had constructed an input-output table of their economy. The number has increased sharply in recent years. See Hollis B. Chenery and Paul G. Clark, <u>Interindustry Economics</u>, New York: John Wiley and Sons, Inc., 1967, p. 183.

choice, though extremely important in economics, does not constitute its single core, and many other views spread throughout this study.

The above comments should not give the impression that the problem of rational choice and its systematization in the discipline of praxiology, is not of central significance in economics. In fact, the discussion of the von Neumann and linear programming problem in this chapter indicate the significant role that optimization plays in economics. Also familiarity with the dynamic version of the Leontief model or the linear programming generalization of his static model immediately necessitates the application of praxiological concepts and methods.[125]

The important point to note is that praxiology is an auxiliary discipline to economics (and to many other sciences) and that reducing economics to praxiology amounts to its liquidation as an empirical science. The development of economics as an empirical science necessitates a total reexamination of the praxiologico-subjectivistic trends that have haunted the science since the last quarter of the nineteenth century.

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[125]These models are not discussed in the present study. The following constitute some basic references: Leontief, Studies in . . . Chapter III, including "Mathematical Notes" I and II; Dorfman, Samuelson, and Solow, pp. 283-305. Leontief can eliminate the problem of choice at the expense of "causal indeterminacy" of his system. See Dorfman, Samuelson, and Solow, pp. 295-300.

Since consumption is for the most part an individual activity, and since consumption, being the end of all economic activity, is assigned the position of the single core of theoretical analysis in the subjectivistic conceptions of economics, it follows that all economic theory can be understood by the "mental processes" or the consequent behavior of an isolated individual in a desert, or on an island. Hence, the popularity of the Robinson Crusoe science fictions among the subjectivist circles. Thus the subjectivist school not only abstracts from the empirically-observed invariances such as those referred to above, but also ends up with abstracting from the very "socialness" that characterizes the state of human existence. The ultimate premises of this conception is that human consciousness is an extra-empirical phenomena that is independent of his social existence. This is, of course, nothing but philosophical idealism descended upon economics by the Australian School. It has penetrated economic science to its very core. Subjectivism has become the very kernel of the prevailing economic theorizing. The efforts of Marshall to "bring in the production side" with his partial equilibrium scheme will not do.[126] Nothing short of a total reexamination of economic science on all levels--metaphysical, epistomological, methodological, and analytical--will purify the science from its "Australian ingredients."

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[126] An appraisal of partial equilibrium method is given in section 9 of this chapter.

Contrary to consumption, production is an objective social process. The development of technology and the process of division of labor binds men into an ever more complex network of interrelationships. If it is remembered that it was fundamentally the progress in division of labor (and the accompanying accumulation of capital) that undermined the self-sufficiency of the economic units within the natural (or traditional) economy, transforming it into an organic whole--integrated and indecomposable--and if it is remembered that the very principle of economic rationality was a consequence (and not an antecedent) of the process of division of labor, and if it is further noted that the process of division of labor is for the most part an autonomous one, feeding on the cumulation of the experiences of innumerable generations of men, it is easy to see why production should occupy a central position of attention in the study of economics. This also explains why the Leontief model, which is essentially a model of production, has proved to be so fruitful both in descriptive as well as in analytical economics. In fact, the models of von Neumann, Leontief, and process analysis all have in common the characteristic that production occupies a central position in the theoretical model and its empirical counterpart. In a preceding section the significance of the concept of "activity" was appraised in this regard.

It is, therefore, clear that the methodological problem in economics today is not merely a tactical one of shifting around some axioms of this or that theory, or developing still more efficient techniques of indirect inference in econometrics. It is, rather, that of the fundamental orientation of the science; it is the problem of objectivism versus subjectivism, the problem of qualitative versus analysis, speculative versus verified knowledge, extra-empiricism versus factual analysis. In short, it is the difference between metaphysics and science.

In specific terms, there exists a tendency in economics towards the view that science is born when one can answer the "why" of things and processes. Hence, the preoccupation with why businesses and consumers do what they do to the exclusion of the conditions under which they act. The state of technology, the state of preferences, and the state of natural and other resources attract minimal attention and the problem of motivation of economic agents--the most inaccessible and subjective aspect of the science--the problem of choice, is presented as the whole of the science.

Even the present state of preferences is not systematically described as a framework within which choices are made, although this problem can be quantitatively studied by compiling a highly detailed table of the composition of demand and studying it for possible existence of invariant patterns within it. However, a relative stability of the composition of demand is the very indispensable condition in the absence of which producers would have no way of knowing what to produce. The fact that the composition of social demand is the result of preferences which are deeply rooted in customs, habits, physiologico-cultural needs of people, changing only slowly and often in a predictable manner, completely escapes the attention of economic theorists. They speak of choice and preference not with reference to a particular cultural environment with its empirically stable and only slowly changing preferences but in an unspecified milieu, in vacuum.

Schumpeter, though unable to grasp the far-reaching methodological implications of the invariant relations that are based on custom, habit, and technology, expresses the significance of this point in the following passage:

> . . . We shall outline the leading characteristics of a mental picture of the economic mechanism. And to that end, we shall primarily think of a commercially organized state, one in which private property, division of labor, and free competition prevail.
>
> If someone who has never seen or heard of such a state were to observe that a farmer produces corn to be consumed as bread in a distant city, he would be impelled to ask how the farmer knew that this consumer wanted bread and just so much. He would assuredly be astonished to learn that the farmer did not know at all where or by whom it would be consumed. Furthermore, he could observe that all the people through whose hands the corn must go on its way to the final consumer knew nothing of the latter, with the possible exception of the ultimate seller of bread; and even they must in general produce or buy before they know that this particular consumer will acquire it. The farmer could easily answer the question put to him: <u>long experience, in part inherited, has taught him how much to produce for</u>

> his greatest advantage; experience has taught him to know the extent and intensity of the demand to be reckoned with. To this quantity he adheres, as well as he can, and only gradually alters it under the pressure of circumstances.[127] (Emphasis added, M.M.)

The "experience" that Schumpeter refers to implies some stability in the behavior of those to whom the farmer sells his produce. If the farmer can take advantage of this stability in planning how much of what he ought to produce why cannot economic science do likewise. The farmer is definitely predicting. Economics must be able to predict even more consistently and systematically because it is a science The basis of this prediction is the existence of a definite composition of demand that changes not capriciously with no reason but systematically, gradually, and often with definite and identifiable reasons. Thus it is necessary to have access to a detailed and systematic picture of the present state of the composition of social demand.[128] Its future status can be inferred from its present state with the help of empirically-formulated theories of consumption.

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[127]Joseph A. Schumpeter, The Theory of Economic Development, trans. Redvers Opie, New York: Oxford University Press, 1966, pp. 5-6.

[128]The advertising agencies know very well that consumers' demand is (1) rather stable and difficult to change, hence needing "repeated stimuli" continued systematically; and (2) it is not capricious and unpredictable in its entirety or in its parts. Such capriciousness is negligible in relation to the stability observed.

Barna draws attention to the stability in consumption patterns as being similar to that in technological patterns:

> the variation in behavior between households is perhaps wider than in that between firms, although this is not yet confirmed by empirical evidence. But if any sizable group of households is taken, their behavior in the aggregate shows remarkable stability from one year to another. It is true that various behavior relations change through time but this change is slow and gradual. From an analytical point of view there is thus little difference between behavior relations relevant to households and technological relations relevant to industry; indeed, technological change is often more abrupt than change in behavior. In surveying households too much attention is often paid to short-term changes and too little, perhaps, to the stable underlying needs for food, shelter, clothing, amusement and art. These needs remain practically unchanged from one generation to another and it is only the ways in which they are satisfied to that change; the chemist has replaced the work of the silkworm but the final product has not fundamentally changed.[129]

It is, therefore, seen that the invariant relations that constitute the main subject of an empirical science are not absent in economics. They exist not only in the area of production but also in the sphere of consumption. It is, therefore, not whether a theory is "consumption-oriented" or "production-oriented." It is rather the manner in which production and consumption are treated in a theoretical setup.

The question ultimately boils down to whether the abstraction of a science are based on systematic observation and/or experimentation and subject to direct or indirect verification or they are

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[129]Barna, pp. 24-25.

speculatively derived from limited and non-systematic observations and not directly or indirectly verifiable. Put otherwise, it is the problem of discovering invariant empirical relations within the domain of a given science as opposed to offering impressive theoretical constructs with little empirical significance. By now it is well established that theories with remarkable internal consistency but little, if any, empirical validity, are not limited to those found in folk superstitions such as theories of creation, of origin of man, of the shape and position of the earth.[130] In science of recent centuries, economics and psychology have demonstrated the possibility of building an edifice of interrelated concepts with no more than a limited set of casual observations stated in few axioms. In both cases "wrong" abstraction, incorrect angle of looking at the problems are responsible for such departures from the position of an empirical science. It was seen that in psychology Freud "looked" at the subject's dream and recollections,

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[130] One such "theory" is preached by Moslem mullahs to the rural (and generally uneducated)segments of the population in Iran. It runs as follows: The earth rests on one horn of a giant bull, the bull stands on the back of a giant fish (a whale?), which swims in foam at the surface of the ocean that fills the rest of the universe. This theory is successfully put to work to "explain" earth quakes, thunder, rain storm, etc. Earthquakes occur because the bull being tired of holding the earth on one horn gently shifts it to rest on the other! Thunder is nothing but the roaring of the bull showing his anger, and rain storms are the result of the whale's splashing of the ocean's water when it accidentally goes lower than usual from foam into water. The range of phenomena consistently "explained" by this "bull-whale" theory is remarkably wide.

whereas the task is to look at the objective and invariant modes of motion of human nervous system, reflexes--conditioned or unconditioned--and cerebral physiology, on the one hand, and social environment--with its relatively constant set of customs, habits, economic and sociological position of individuals--on the other hand. Freud's subjectivism is here contrasted with Pavlov's objectivism.

In economics, the subjectivists look at the exchange process and the market and infer that the optimizing behavior constitutes the whole of economics, whereas the task is to look at the empirically invariant relationships in production and consumption within a social framework (as opposed to Crusoe's island or desert).

Neither the phenomenon of dream or recollections of memories nor the phenomena of exchange and optimizing behavior are to be discarded as irrelevant or uninteresting in these sciences. On the contrary they are essential aspects of the two sciences and must ultimately be explained. The question is not the relevance or significance of these phenomena, for they are definitely relevant and significant. It is, rather, whether or not they constitute the best window for looking at a wide range of phenomena within the domains of the given sciences. It was seen in the discussion of the Walrasian general equilibrium model in section 6 of this chapter that the exchange process and the market provide poor points of departure for understanding of economic phenomena. The correct place to start is the systematic description by direct observation of the relatively constant patterns of preferences, technology, resources, and the world environment of the given economy. The market phenomena of prices, and output is best explained in terms of the overall interrelationships between various economic agencies with respect to these fundamental economic data not on the basis of some doubtful psychological axiom about some "perfect consumer" in some "perfectly competitive" system. Thus the methodological problem facing the science is the legacy of the Austrians and Marshall: subjectivisms due to the Austrians and partial equilibrium due to Marshall. These two aspects of the science, far from being independent, are inherently interrelated. In the next section the method of partial equilibrium will be examined schematically.

9. Concerning Partial and General Equilibrium Analysis

Partial equilibrium analysis is the analytical engine of methodological idealism and theoretical typicalism. The specification of an "ideal system" in which the "typical firm"[131] or "typical consumer" functions is essential to the partial equilibrium analysis. It is focally dependent on *ceteris paribus* assumptions: factors are "mentally" assumed fixed which in reality vary capriciously. Thus,

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[131]The introduction of monopoly, duopoly, oligopoly, etc., in the analysis actually amounts to introducing "types within a type."

in the absence of empirical invariances, artificially assumed invariances are provided as a springboard for theoretical analysis. The method is, therefore, in general non-empirical in the sense that the *ceteris paribus* assumption involved is, in general, of purely intellectual significance.

This should not imply that partial equilibrium analysis is entirely devoid of significance. In so far as the intellectual exercise of *ceteris paribus* is concerned, other sciences utilize the approach with benefit. Ernst Mach has demonstrated its importance in physics.[132] Morgenstern referring to the approach as thought-experiment, writes that:

> Obviously the thought-experiment has been widely used in economics as in all sciences. It has played a very large role in Einstein's hand. Its methods involve imagining conditions that differ from the known conditions and then attempting to identify the proper factor to which the imagined variations could be ascribed. This procedure consists in the drawing of implications and like other experiments may lead to the discovery of new facts. It is legitimate but exceedingly difficult to handle, hence the numerous times when it has given rise to poor results. It is *often restricted to qualitative considerations* [emphasis added, M.M.]. . . . [A very important] difficulty lies in the fact that 'known, given' conditions are only very imperfectly known so that one may argue from a rather shaky basis. . . .[133]

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[132] Oscar Morgenstern, *Economic Activity Analysis*, New York: John Wiley and Sons, Inc., 1954, p. 486.

[133] *Ibid.*, pp. 486-487.

Thus even if thought-experiments in economics were comparable with those in other sciences they would still have to constitute only a supplement to not the whole of analytical work in the science. This is so because of (1) intricacies of the method which lead to poor results frequently; (2) the difficulty of knowing what should be treated as "given, known" in a particular economic situation; and (3) the purely qualitative results of this type of analysis.

It should be noted, however, that the assumption that thought-experiments in economics are methodologically comparable, --beyond some superficial resemblance--with those in physical sciences is unwarranted. As it was pointed out in a different context earlier in this chapter,[134] thought-experiments in physical sciences often have much indirect support by other theories in the given science which have been empirically verified. Thought-experiments in this case are usually considerations of some limiting cases of laws that are experimentally verified. Further, rather than using the term ceteris paribus, these science usually enumerate the set of conditions to be held fixed. The loose and general requirement ceteris paribus in economics actually amounts to the confession that one does not know what specific factors are to be treated as fixed in a given situation. That is, not only the quantitative but also the qualitative specification of parameters--the

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[134] See section 3 in this chapter.

list of factors to be treated as given--is indeterminate. Ceteris paribus thus implies quantitative and qualitative indeterminacy of economic parameters.

In spite of the above comments the limited usefulness of partial equilibrium analysis cannot be denied. The limited success of partial equilibrium analysis lies in the fact that it looks at the economic universe from the same angle as consumers and firms do. This means that the qualitative indeterminacy of parameters is removed, at least in part, by treating those factors that are outside the control of the individual decision-making unit as parameters. In the case of a given consumer or firm these factors are generally known. For example, a small potato farmer treats the price of potatoes as given and adjusts his output accordingly. Therefore, partial equilibrium model that attempts to explain the behavior of a small producer in a competitive market, price is treated as a parameter. The legitimacy of this type of analysis should not lead to an underestimation of its limitations. It should not blind one to the need for more powerful techniques. Partial equilibrium analysis is, after all, little more than a formalization of the views of consumers and firms for whom the economic environment is given. There is no guarantee that this environment can be grasped in its essentials merely by adding the relationships that one deduces by observing the micro-units. In particular, partial equilibrium analysis cannot be modified, summed, or integrated, to reveal two fundamental characteristics of the economic environment: (1) its internal balances; and (2) its internal structure.

Concepts of internal balances and structure are of central importance to the theory of general equilibrium. In terms of general equilibrium theory

> the economic system can be viewed as a gigantic computing machine which tirelessly grinds out the solutions of an unending stream of quantitative problems: the problems of the optimal allocation of labor, capital, and natural resources, the proper balance between the rates of production and consumption of thousands of individual goods, the problems of a proper division of the stream of current output between consumption and investment, and many others. Each of these problems can--in principle at least--be thought of being represented by a system of equations. Under conditions of perfect competition an impersonal automatic computer--to which we usually refer to as the economic system--has been solving these equations year after year, day after day, before the mathematical economists even though of constructing their systems.[135]

In a general equilibrium model[136] there may be few or many equations depending upon the "coarseness" of the model. These equations consist of two kinds: the balance and the structural

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[135] Leontief, Essays . . . , pp. 237-238.

[136] The following discussion of general equilibrium theory implicitly refers to the Leontief static model. However, the general considerations in relation to the balance and structural equations are true of all general equilibrium models such as those of Walras, von Neumann, Wald, etc.

equations. The balance equations state that in each period of time for every good, the total production and total use must be equal when proper allowance is made for exports, imports, and additions to or subtractions from stocks.

The structural equations describe quantitative relationships between the inputs absorbed and outputs supplied by each sector. Input-output tables constitute one of the ways in which the parameters of the structural equation may be numerically specified.

The general equilibrium analysis takes cognizance of the fact that a modern economy consists of highly interrelated parts and attempts to provide a numerico-mathematical analogue for this system. It seeks such invariances as the input-output relations among the sectors of the economy--relations that change slowly and, in part, predictably. Its parameters are well specified and empirically determinable. What is assumed as given--that is, the state of preferences, technology, and resources--is not only well-defined but also enjoys relative constance in its entirety. Hence, the "given conditions" are empirically given; they are not assumed as being given by mental abstraction. Because of these considerations, the general equilibrium model can lead to quantitative as well as qualitative analysis; this in contrast to the purely qualitative results of partial equilibrium analysis.

Because of the quantitative character of general equilibrium analysis, observation and classification of facts find immediate significance in this area of theoretical economics. In fact, the systematic interplay between fact and theory did not begin until the possibility of statistical implementation of general equilibrium models was demonstrated by Leontief. No wonder that the problem of classification of economic facts has attracted so little attention until recently. Leontief's insistence on the constancy and objectivity of "sectors" in an economic system is reminiscent of Linnaeus's insistence on the constancy and objectivity of species. Just as Linnaeus provided biology with its first systematic framework for observation and recording of data, Leontief has provided economics with such a framework plus much more: a powerful analytical scheme that goes far beyond the task of systematizing data, providing novel approaches to the solution of many economic problems. The non-empirical nature of partial equilibrium analysis was hardly a theoretical guideline for such work. In fact the problem remains amazingly unexplored to this very day, though some interest has been expressed in the field by a few authors, mostly in association with the input-output works.

The development of economics as an empirical science is, therefore, expected to occur along the lines of general equilibrium models--models of static, dynamic, linear, non-linear, deterministic, stochastic, and other varieties. The general equilibrium models must constitute the very core of pedagogical efforts in economics. The sooner this is done on a wide scale, the more rapid the development of the science. Partial equilibrium analysis should be pushed to the side as a supplementary method, only useful for a very rough first approximation in relation to some specific problems. A good portion of it is expected to be reduced to nothing more than a matter of records, a chapter of historical curiosity in the development of economic science.

10. Econometrics and Economic Empiricism

The modern school of economic statistics and econometrics has made stupendous efforts to narrow the gap between economic theory and empirical reality by attempting to give statistical specifications to the statements and theorems of economic theory. But this school has, for the most part, uncritically accepted the methodological maxims of economic theory. Specifically, microeconomics and its analytical engine of partial equilibrium analysis, macroeconomics and its heroic aggregates--super-aggregates of an overall production function for the economy as a whole with its overall inputs of land, labor, capital--and preoccupation with "misplaced exactness"[137] speciously manifested in nonlinear formulations of Cobb-Douglas, constant elasticity of substitution (CES), and other production function;

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[137]See section 5 of this chapter on the significance of nonlinearity assumptions in economics.

these are characteristics of the approach of econometricians, essentially following the footsteps of economic theory.

In this study no more than some general consideration can be offered about the role of econometrics in economic science. Neither an evaluation of the empirical results of partial, micro-relations of supply, demand, and production function, nor that of the econometric macro-models is feasible within the scope of the present work. However, since aggregative concepts and relations characterize econometric works both at micro and macro-levels, and since the nature and methodological significance of aggregative formulations is examined in detail throughout this work, it follows that the econometric school is automatically examined here in so far as the economic content of its methodology of econometrics, inclusive of its much refined and original statistical techniques, that constitutes a separate problem whose evaluation is unrelated to the present study.

In one fundamental way econometrics resembles economic theory. This is pointed out by Leontief:

> In the same spirit in which pure economic theory aims at deriving the greatest number of possible conclusions from a few fundamental assumptions, the modern statistical school with utmost ingenuity explores various methods of drawing the largest possible set of statistical inferences from a small and strictly limited number of direct observations.[138]

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[138] Leontief, Studies in . . . , p. 5.

In its tendency to follow themethodology of economic theory, econometrics finds itself more and more in the sphere of indirect statistical inference and away from direct observation on the multitude of qualitative differences that characterize objective reality. Thus economic empiricism is deprived of any morphological basis of observation and measurement similar to those in biology and other sciences. It is the great merit of Leontief's input-output approach to have shoen the possibility and significance of such a direct approach to the economic reality.[139]

This is not to mean that indirect statistical inference is of no value to economic empiricism. On the contrary, in certain cases the method of indirect inference may be the only one available. The problem is that "undue and exclusive emphasis on indirect statistical inference in some of the more recent empirical studies has at times put on this useful, nay indispensable, tool of empirical analysis a burden which it actually cannot possibly sustain."[140]

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[139] Aware of the significance of this aspect of his scheme, Leontief writes: "Input-output approach is consciously aimed at concentration of the empirical data-gathering phase of economic analysis on direct observation of the basic structural characteristics of the particular economy concerned. All its operational properties are t then derived deductively, i.e., computed through insertion of these primary empirical data into appropriate theoretical general equilibrium formulae." See Leontief, "Input-Output Analysis and the General Equilibrium Theory," in Barna, pp. 43-44.

[140] Leontief, Studies in . . . , pp. 6-7.

In principle it is possible to specify the empirical components of a theoretical model either by means of observation and measurement or through indirect statistical inference. For example, the production function of some particular industry can be obtained directly through collection of the relevant technical, engineering information or it can be determined by way of a rather intricate interpretation of the supply-demand reactions of the industry. Leontief notes that:

> In the latter case the relations between the data and the unknown variables become actually opposite to those which exist in the formal explanatory scheme. Instead of considering the technical production function as known and deriving from it the unknown price and output reaction of the industry, the statistician, in the process of indirect inference, takes the price and output reactions as 'given' and derives from them the unknown shape of the underlying production function.[141]

This corresponds to the economic theoretician's insistance that the exchange process, the market relations, rather than the fundamental technical data constitutes the appropriate point of departure for theoretical works. Thus the method of econometrics is shaped and conditioned by that of economic theory. The success of econometrics pends a radical shift of emphasis from market to the fundamental data in theoretical formulations, along the lines suggested in the preceding sections.

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[141] *Ibid.*, p. 6.

These critical comments on econometrics may sound strange in the face of the much popularized "success" of "econometric models of the United States" such as Klein's "quarterly" model, its modification by the Office of Business Economics (OBE), the Fromm model, and others. Fortunately, the timely evaluation of these models by Stekler in his 1968 article[142] has provided an objective picture of the status of these models. After showing that these models are essentially no better and occasionally poorer than the so called naive forecasting methods, he concludes that "the combination of all the results suggests that econometric models have not been entirely successful in forecasting economic activity."[143]

The methodologically strong feature of the existing econometric macro-models is that they take cognizance of two fundamental characteristics of the economics system--its dynamic and general interdependent features--and attempt to incorporate these in their theoretical formulation. It is to be noted, however, that it is not a mere recognition of the general interdependence and dynamic character of the economic system that renders an empirical model of the economy useful as a predictive device. The important thing is the specific manner in which these features are incorporated into the model. The

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[142] H. O. Stekler, "Forecasting with Econometric Models: An Evaluation," Econometrica, July-October, 1968, pp. 438-463.

[143] Ibid., p. 463.

ultimate test is whether or not the model provides a set of empirically invariant structural relationships which are sufficiently constant over time or change predictably enough to make forecasting possible. But macro-economic models pay little attention to this point. Their individual relations involve highly aggregative concepts which consist of tremendously heterogeneous conglomerations, completely suppressing the numerous qualitative differentiations of the primary data. For example, in their 36 equation (and 27 identities) model for "econometric gaming," Klein, Evans, and Hartley apply variables such as the following:[144]

C_a = consumer purchases of automobiles and parts

C_d = consumer purchases of durables

C_{na} = consumer purchases of nondurables and services

C_p = index of capacity utilization, full capacity = 100.0

I_p = total fixed business investment

I_{pf} = farm fixed business investment

I_{pf} = manufacturing fixed business investment

K, capital stock, L. labor force, PI, personal income, GNP, gross national product, etc.

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[144] L. R. Klein, M. K. Evans, and M. Hartley, Instruction Manual to accompany Econometric Gaming: A Kit for Computer Analysis of Macroeconomic Models, London: The Macmillan Company, 1969, pp. 9-12.

What characterizes this model is not only the highly aggregative nature of its variables but also the more-or-less arbitrary disaggregation along institutional rather than functional lines, following the footsteps of national income accounts. For example the distinctions between consumers' durables and nondurables, farm manufacturing, non-farm and non-manufacturing investment, indicate that the classification scheme utilized lacks any inified basis--such as, for instance, the industrial classification of input-output models--and applies such widely different criteria as the degree of durability of goods, sectoral origin, or ultimate une-destination of goods.

The result of heterogeneity of the aggregative measures and the associated arbitrary classificatory scheme in the model shows itself in significant variability in the quantities exogenously estimated or endogenously determined, to the detriment of determining the degree of error involved. Klein and Evans confess to this serious weakness:

> . . . Each equation (in the model) is disturbed by random errors, but our numerical estimates of the equations replace e_{it} by their expected (average) values, namely, zero. This is easy enough to do, although it obscures the variability and degree of reliability of forecasts.[145]

It is commonplace to note that statistical measures of expected value, like other statistics, are worthless in the absence of specification of the variability in the population represented by the

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[145] *Ibid.*, p. 3.

given expected value. In the aforementioned model hundreds of such measures are involved in repeated computations. It will indeed be an astonishing result if such models truly came close to simulating reality.

Referring to the importance of specifying errors in empirical works, Professor Morgenstern notes that:

> Qualitative description of errors is an indispensable preliminary step. It makes possible, for example, at least conclusions as to whether certain aggregations or computations would tend to cumulate or to offset the errors. This would be valuable information even if no further numerical estimate is possible at the moment. Apparently, economics would have to go through a stage of such qualitative description in order to arrive at more precisely expressed quantitative measurement of errors.[146]

Not only must errors be measurable but also they must be absent as far as possible. Errors of measurement can be minimized by means of more systematic and careful practices which improve with experience. But errors in the actual population on which measurement is made is the result of choice of variables, aggregates, and averages. The strategy of "model building" should be oriented towards the singling out of those variables and relations of an economic system that exhibit considerable invariance or predictability of behavior. In their empirically differentiated states economic phenomena enjoy tremendously stable patterns in relation to the fundamental data of

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[146] Morgenstern, On the Accuracy. . . , p. 53.

preferences, technology, and resources.[147] It is when this empirical differentiation is suppressed through averaging and aggregation that the interrelationships begin to manifest significant errors, or "disturbance terms." Too often student of economics are given the impression that sizable variability is an inherent characteristic of economic variables. They are not told that it depends on the nature of the model's abstractions as specified in the body of variables and equations and identities relating these variables together. Constancy and objectivity of the fundamental setting of an economic system is an indispensable precondition to the more or less orderly observed functioning of the system. Consumers and firms understandably count on such regularities and constancies. They could not survive if they were to make new, non-habitual decisions about every aspect of their economic activity everyday, every month, or even every year anew. Learning often involves cost. The weight of new decisions to be made in a given day in the economic system is insignificant relative to the more or less habitualized, automatic acts that go on by consumers and firms.

Economic theory has suffered (and is still suffering) from an illusion of <u>change in absolutio</u> to the extreme of closing eyes to those aspects of an economic system that do not change or do so only

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[147]See section 6 of this chapter regarding the notion of invariance in economics.

gradually and more or less predictably. To conceive of change as absolute is a no less serious methodological (and necessarily philosophical) error than to idealize constancy (or lack of change) as the fundamental characteristic of universe, economic or otherwise. To seek an explanation for change without at the same time looking for explanation of lack of change is a fundamental error, for change and lack of change inseparably define existence--they are the opposing but mutually indispensable poles of the same entity.

The task of econometrics is not merely to assume some relations between a few economic variables but rather a systematic search for empirical invariances--features of economic reality that are relatively constant--in terms of which the observable changes in the system can be explained. Little explicit recognition of this methodological principle is found in the literature of econometrics. In fact the consistent emphasis in the field on the use of aggregative measures and indexes is the surest way to guarantee that economic variables and equations in econometric models will continue to be characterized by extreme volatility innocently called "random disturbances." The neutrality of this term stands in sharp contrast to the colossal methodological errors that lies behind it, namely the bad choice of variables, undue aggregation, and wide use of index number. These are errors of a strategic type. Their removal requires a radical transformation of economic theory. This task goes beyond the conventional limits of econometrics.

It is important to note that simply more efficient econometric methods cannot overcome the fundamental methodological problems of economic theory. It should be remembered that, in general, economic magnitudes are generally measurable in their actually differentiated states when data are collected. Economic analysis, however, is limited to purely qualitative results. The difficulty of quantitative analysis does not lie in the nature of economic facts, for they are for the most part quantifiable. It is rather the weakness of the analytical engine which is responsible for this outcome.

11. Some Modifying Comments

In discussing the methodology of economics as an empirical science and comparing it with the method of other empirical sciences, this study is not seeking to establish exact parallels between the details of the methods of various disciplines considered. Nothig of the sort is intended. The specific nature of method, set of tools, and analytical techniques of a science are developed in response to the character of the given science itself. For example, microscope in biology, telescope in astronomy, and wind tunnels in aviation science indicate that each science make use of different experimental, observational, and analytical tools, these tools being selected and adapted to the nature of the phenomena that constitute the domain of investigation of the particular science.

It is the generic feature--as opposed to the particular characteristics--of the empirical sciences that is of interest to this study. The assumption adhered to is that, although each science has its own particularities of approach to the study of phenomena, there do exist some general features that characterize all the empirical sciences. The interplay of fact and logic expressed in the processes of induction, deduction, and reduction in the method of empirical sciences constitutes such general features.

A second point to be clarified has to do with the widely prevalent view that certain macro-economic phenomena are stable not because of stability in the underlying micro-relations but in spite of observed instability in the latter. This is entirely possible but the empirical existence of such relations in economics is to this very day widely disputed. The two most talked about "constants" in macro-economics today--the "multiplier" and the "velocity of money"--have proved more convenient in teaching economics than in guiding policy. The impacts of fiscal as well as monetary policy can be predicted only in terms of direction of change, leaving out the question of the magnitude of the effect as well as the time duration between the application of the policy measure and the beginning of its impact. Further, the process of diffusion of the given measure is generally not specified. The diffusion process discussed in the illustration of the multiplier is an elementary step in this direction, and to that extent it does provide some insight into the nature of the process.

The point to note is that even if there are a few fairly stable macroeconomic relations, this does not eliminate the need to explain this stability. It is not stability as such but stability that is understood on one basis or another that can be useful in science in general and in macroeconomics in particular. Unless it is understood what causes a given macroeconomic relation to be stable one is never sure whether this stability can be counted upon in the future or not.

An interesting historical event in this regard is the widely held prognostication of many economists during the World War II years that wid-scale unemployment would follow the cessation of hostilities. As is well known this prediction did not materialize and subsequently it was realized that the accumulation of liquid assets in the hand of the consumers during the war years as well as the pent-up demand for consumers' durable goods were among the major factors that "shifted" the consumption function upward. Further, it was realized that the observed stability of the function and the high degree of correlation between income and consumption is fully compatible with an actually unstable function, continually shifting its level. These episodes in the development of macro-economics are too well known to require any detailed repetition or references here. The point to note is that stability by itself is not sufficient in order for a macro-economic relation to be valuable as a scientific entity. In addition, it is necessary to know the reasons behind this stability.

Reference is often made to social psychology and molecular theory of gases to draw attention to the fact that some phenomena may be predictable when a large number of people or molecules are present. In such cases, it is said that the behavior of the group is not reducible to and understandable by means of the behavior of individuals in the group. This point is not disputable. But it is not the logical possibility or impossibility of such phenomena that is the issue. It is, rather, the extent to which such an approach bears fruitful empirical results.

Thus this study does not assume a priori that disaggregation is, because of any logical necessity, superior to the aggregative approach. Rather, it is argued that disaggregation as a strategy of theory formulation may prove fruitful. It is more the question of emphasis on the aggregative versus the disaggregative formulation that is explored. Neither approach is to be abandoned in favor of the other. If at times the discussion gives an emphatic support to the disaggregative approach, it is either because the latter has been excessively overlooked by economic theorists and the study finds it necessary to point this out, or because the particular discussion leads to a conclusion in favor of the disaggregative approach.

Therefore, while the study points out some of the pitfalls of the aggregative formulations, by no means does it advocate a complete abandonment of the approach in future research.

The above argument is--in its essentials--also applicable to the question of whether linear or nonlinear formulations of economic relations is to be preferred. Again the study does not propose that one should be abandoned in favor of the other. Some phenomena may lend themselves to nonlinear formulations with good empirical results. In some other areas a linear approximation to the actually nonlinear relation observed may simplify the model and its computability significantly. As a matter of being "closer to reality" nonlinear formulations are likely to be superior. This is so because, in a formal sense, nonlinear formulations are infinitely more flexible than the linear ones. Indeed, a linear formulation can always be regarded as a special case of some more inclusive nonlinear formulation. But since when the number of independent relations in a model is large the existence of nonlinearities is very troublesome both mathematically and computationally, it is often necessary to resort to linear formulations, for the choice is really between a linear approximation model that can be statistically specified and a nonlinear one that cannot. If the nonlinear system could be solved, conceivably it would give better results, but the problem is that it cannot be solved.

Thus the study explores some of the pitfalls of nonlinear formulations in economics, not denying that such formulations may at times be the only acceptable ones. Again the problem is not that of excluding one of the two from economics. Rather it is the shift of emphasis that is of interest.

12. An Overview

In this rather lengthy chapter many aspects of methodology of the economic science have been examined. The scope and variety of topics renders a meaningful and concise summary of the chapter impossible. A schematic summary is provided in the introduction section. It is necessary to have an overview of the highlights of the chapter in order to specify explicitly its relationship with the rest of the study for the sake of a quick reference. This section aims at providing such an overview.

Theoretical work in an empirical science aims at discovering various types of "order" in that science's domain of inquiry. Order may be of a simple type such as that which enables men to comprehend things around them. It may be of a more complex kind such as "causal order." It may be still more complex such those expressed in elaborate scientific theories. But the generic feature of all these (and other) types of order is the concept of invariance.

By invariance is not necessarily meant absolute lack of change such as is implied in mathematical invariance. It is rather relative invariance that is of relevance in empirical sciences. Here certain aspects of reality change much slower than other aspects, and at times the direction and/or magnitude of their change is predictable. For example the technology of a society is characterized by a tremendous inertia. Processes are continually refined, modified, and improved, but this refinement, modification, and improvement occur (1) relatively at a slow pace, and (2) in a more or less predictable fashion. It is true that the dynamic technology of a modern economy is continually feeding on a stream of new inventions and innovations which continually tend to change its present features. But, relative to the colossal number of processes that go on for the time being in their existing manner, these changes are rather small. Further, many inventions and innovations wait for some time after their discovery before being actually introduced. This makes prediction possible in principle.

Similar invariances were discussed in relation to preferences and natural resources. Thus it can be seen that economics is well endowed with an appreciable degree of invariance in its fundamental data of technology, preferences, and resources.

But these empirical invariances reside in the vast qualitative differentiation of technological processes, people's preferences, and natural (and other types of) resources. It follows that economic theory, if it is to take advantage of these empirical invariances as a springboard for prediction and theoretical reasoning in general, must be formulated in such a manner that it would allow for vast qualitative differences actually observed. In other words resort must be made to the formulation of highly disaggregative models such as those of Walras, von Neumann, and Leontief.

However theoretical disaggregation, though a necessary step, is not sufficient for this purpose. In addition to this the structure of the theoretical model must reflect empirical invariances, the elements of the theory must be rather stable. The concept of process, which is the most elementary notion in the models of Leontief and von Neumann and is directly involved in the determination of the structure of these models, satisfies this requirement. The Walrasian model, however, which has as its elementary relations the supply and demand equations for various commodities fails to comply with this requirement because the market relations involved here are, in general, very volatile and empirically difficult, not to say in certain cases impossible, to specify quantitatively.

The partial equilibrium theory, in addition to its focusing on the volatile market relations, altogether abstracts from the notion of economic interdependence and the concept of economic structure which are central to the general equilibrium models. Since economic interdependence is an essential, not to say the innermost, characteristic of the economic phenomena, it is inevitable that partial equilibrium analysis should lead to quantitative indeterminacy in analysis.

limiting itself to certain trivial or doubtful qualitative results. Thus identifying the method of economic analysis with partial equilibrium means the liquidation of economics as a quantitative discipline.

Further, since partial equilibrium analysis abstracts from the interdependence of economic phenomena and since taxonomic work in empirical economics must necessarily center around the characteristic of interdependence of data, it follows that dependence on parital analysis diverts attention from systematic work in empirical economics, bypasses the "natural-history" stage of the science, and prematurely steps into the second stage of deductive theory formation. But because of this severing of ties with their empirical base, theories degenerate into fantastic subjective constructs. Methodological idealism, theoretical typicalism, and aggregation emerge as fundamental characteristics of the economist's approach to the understanding of the real economic system. There emerges a wide gap between theory and the real world. Economic theory and economic empiricism develop their own methods independently of one another. Each is confined to its own incomplete and necessarily limited, not to say useless, analysis. One resorts to index numbers, averages, and aggregates, while the other busies itself with purely deductive constructs with heavy doses of the notions "type," "ideal" system, etc. In short, there develops a fundamental dichotomy in economics separating the discipline into the two compartments of theoretical and empirical inquiry, though the task is the direct opposite of this, namely, the perpetual interplay between fact and theory through the medium of induction, deduction, and reduction, further induction, deduction, reduction, ad infinitum.

Thus the rather commonplace observation that taxonomic work in economics has attracted attention far below a degree commensurate with its importance, and that such (taxonomic) work is an essential step in the evolution of economics as an empirical science, this study has reached the interesting conclusion that the absence of interest in taxonomic work, far from being accidental, is a necessary consequence of the generally accepted and popularized method of partial equilibrium analysis with its associated features of methodological idealism and theoretical typicalism. Thus the above commonplace observation has revealed the significant result that there exist some fundamental methodological problems that tend to impede the development of economics as an empirical science, and that the ignoring of systematic classificatory work in the science is only one of the manifestations of these fundamental methodological problems.

In this and the preceding two chapters the problem of classification and aggregation has been embedded in a methodologico-philosophical framework. Its significance lies in the fact that it constitutes the bridge between the word of face and that of theory.

In the following four chapters the problem will be studied with reference to two specific analytical frameworks in order to explore its analytical significance, attempting to give a rigorous mathematical specification to it whenever possible. The two frameworks chosen are those of Keynes and Leontief.

Several considerations have motivated the choice of these two framework. Only some of them will be referred to at this point:

Very little is available in literature in the manner of treating the descriptive-accounting aspects of the two in a unified fashion as subsystems of a more inclusive frame of social accounting. This is done in the next chapter.

The problem of aggregation and classification within the framework of input-output analysis has been reviewed by several authors but these are usually fragmentary, overlapping, and concerned with one or another aspect of the problem, not treating all its aspects simultaneously against the background of a unified theoretical framework.

The methodological implications of the problem has received no systematic treatment, being limited to a few short passages scattered here and there in the works of Professor Leontief.

Other reasons for the choice of Keynesian and Leontief's systems will be given as these are introduced in the following chapters.

PART II

CHAPTER IV

FUNDAMENTAL IDENTITIES OF NATIONAL INCOME AND INPUT-OUTPUT ACCOUNTING

Input-Output and National Income Accounting are both concerned with providing a framework for recording of facts about the national economy in a consistent manner and in such a way that the interrelationships among the component groups of facts are exhibited in an orderly fashion. Thus, they both aim at describing the national economy quantitatively. To do so, they both engage in heroic aggregations of facts. But the degree of aggregation differs between the two. In fact, as descriptive-accounting schemes, the principal difference between the two is the greater amount of information which is readily obtainable from the less aggregated framework; namely, the Input-Output system.

More specifically, the National Income framework concentrates on the items of "final demand"--consumption, investment, net exports, and government expenditures--and eliminates the "interindustry demand"[1] as "double counting." In contrast to this, the Input-Output framework attempts at measuring the interindustry flow of goods and services. Indeed, the interindustry flows constitute a major portion of the data collected for Input-Output accounting systems.

As a result of disaggregating the national economy into a number of component industries, the items of final demand are broken into a number of components, each of which shows the share of a particular industry for the given item of final demand. Similarly, the "value added" for the economy as a whole is broken into the contributions of the various industries. Formally, it is always possible to obtain the National Income aggregates from an input-output table. These aggregates are readily available in the table and no additional calculation is necessary.

The converse is not true, however. One cannot disaggregate the National Income aggregates into the industrial components without going back to the primary data from which the aggregates were derived. In fact, to obtain information on interindustry flows of goods and services, more primary data are necessary than those utilized for deriving the National Income aggregates.

In some countries national income and input-output

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[1] This is referred to as "intermediate products" in the National Income terminology.

accounting developed independently. The need for unifying the two is acknowledged by many statisticians in the two fields. It is felt that although the two frameworks are designed to serve different analytical purposes, they have important points in common. Some of these were mentioned earlier in general terms. More specifically: (i) both systems aim at giving an overall picture of the economy; (ii) in both cases the method is to record transactions taking place between sectors; and (iii) many entries in the two are identical. "In principle," as Aukrust observes, "input-output accounts may be thought of as an extension of a national accounting system (or vice versa)."[2]

The usefulness of unification is also obvious from an analytical point of view. For example, it would allow an input-output production model to be linked up with traditional macroeconomic models of equilibrium and growth.

This chapter is concerned with the derivation of the fundamental accounting identities of the Input-Output and National Income models. The development of each will be undertaken in such a way that the comparison between the two will be facilitated. The approach taken by Stone and Croft-Murray is most suggestive in this regard

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[2] Odd Aukrust, "Principles of National Accounting," The Structural Interdependence of the Economy; proceedings of an international conference on Input-Output Analysis, Verna, June-July, 1954, ed. Tibor Barna, New York: John Wiley and Sons, Inc., 1955, p. 214.

and will be followed here except for the introduction of a different set of notations which will prove more efficient in the theoretical discussion in the later chapters.

1. A General Framework for Social Accounting

Stone and Croft-Murray have suggested a framework for social accounting which, in its simplest version, can be represented by means of a flow chart. A translation of the framework from diagrammatic to symbolic representation by the use of matrix notation makes it possible to depict an even more detailed and more complex description of the economy. Whereas the flow-chart representation gets complicated very quickly as the number of the interrelated sectors of the economy increases, the matrix notation preserves its simplicity independently of the degree of details involved in the accounting system.[3]

In the following sections, first a flow-chart (or analogue) representation and then a matrix (or symbolic) representation of a general social-accounting framework will be introduced.[4]

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[3]Richard Stone and Giovana Croft-Murray, Social Accounting and Economic Models, London: Bowes and Bowes, 1959, pp. 12-19.

[4]Following Ackoff and Sasieni, a flow-chart description of the economy may be called an analogue model and the matrix representation a symbolic model. "Analogues use one set of properties to represent another set of properties. Contour lines on a map, for example, are analogues of elevation. A hydraulic system can be used as an analogue of electrical, traffic, and economic systems." In fact, a hydraulic analogue of the British economy has been

A. Simple Analogue--Closed Economy

Assume that for each transactor in the economy a set of three uniform accounts are available: one relating to the transactions involved in productive activity, one relating to the use of the gain from productive activity, and one relating to capital transactions.[5] If each account is consolidated over all transactors, then three consolidated national accounts are obtained: production, consumption, and accumulation (or capital transactions) accounts.

Figure 1 illustrates this accounting structure. The accounts are represented by boxes; and the transactions between them, expressed as flows of money, are represented by arrows.

The box labeled "production" represents the productive activity

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developed by the London School of Economics which can simulate the effect of such policy measures as devaluation of the pound, changing of the tax rate, etc., on the economy.

"Symbolic models use letters, numbers, and other symbols to represent variables and the relationships between them. Hence, they are the most general and most abstract type of model." Russel L. Ackoff and Maurice W. Sasieni, Fundamentals of Operations Research, New York: John Wiley and Sons, Inc., 1968, pp. 60-61.

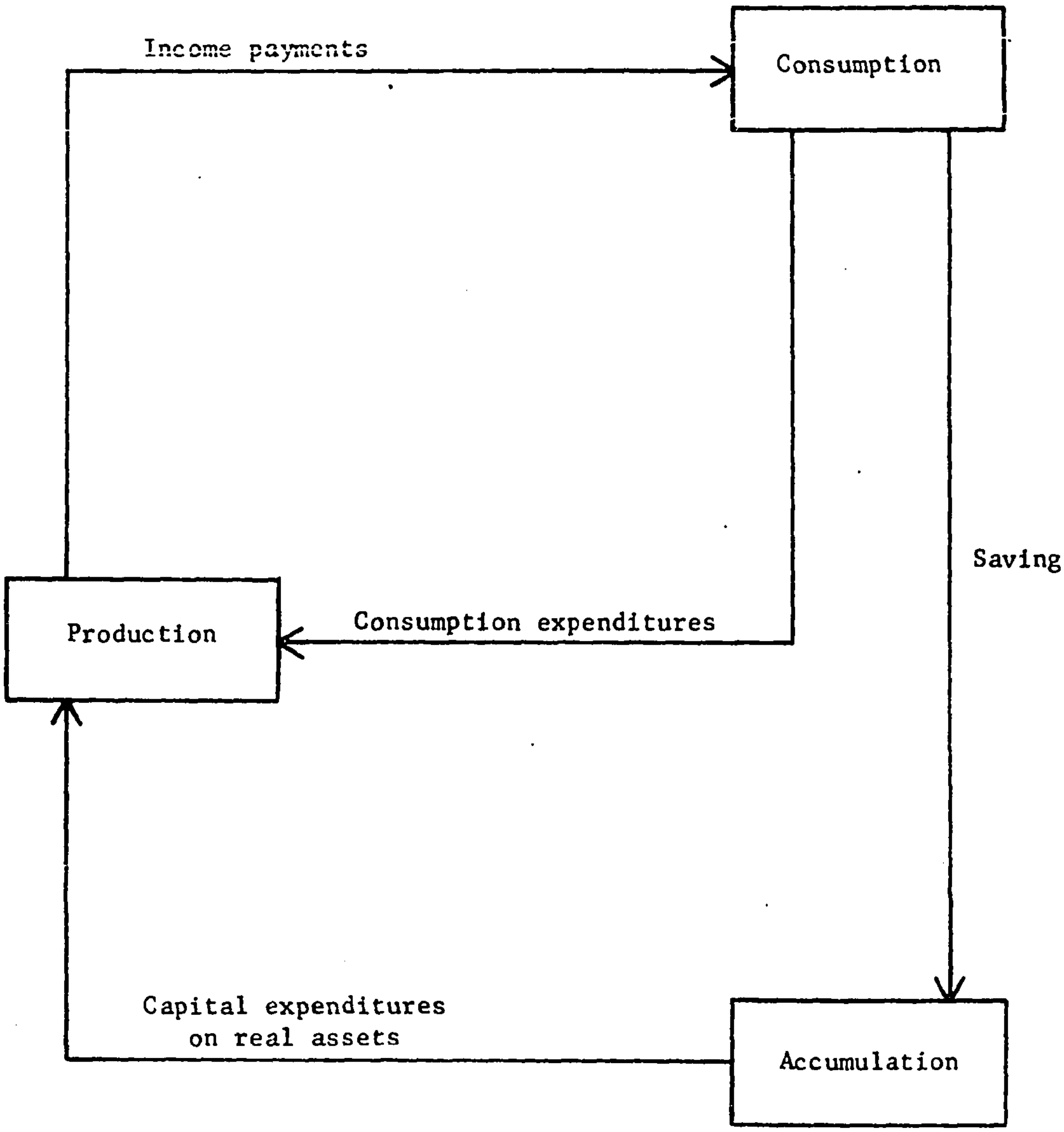
[5]With regard to the term "transaction" Aukrust makes an interesting observation: "My feeling is that the elements we are classifying and measuring in national accounting--and in input-output work as well--are not in fact transactions (interpreted as actions or events), but economic objects. He does not, however, make use of this distinction in his discussion of national accounting due to "a concession" that he is willing to extend to "traditional terminology."
Aukrust, p. 206.

of the whole economy and may be thought of as a consolidated production statement for all the businesses in the economy. These businesses obtain their revenue partly from selling commodities for the purpose of consumption, indicated by the arrow carrying money from "consumption" to "production," and partly by selling capital equipment and similar investment goods for the purpose of accumulating wealth, indicated by the second flow of money into "production." To show the sales of individual businesses to one another, an arrow would start from "production" and return to it. These sales are ignored for the moment.

The whole proceeds of sales by "production" are paid out as income to the factors of production in the form of wages, salaries, profits, interest, or rent and are shown in the diagram by means of an arrow pointing from "production" to "consumption."

The two flows emanating from "consumption" show that the whole of factor income is allocated between spending and saving. Note that "consumption" appears in two different meanings in the diagram. One time it refers to a sector of the economy, the consumers' sector. Another time it refers to a flow of "consumption expenditures' from the consumers' sector to the production sector. The reason for using "consumption"sector rather than the more common terminology "consumers'" sector is that consumers are also producers as well as accumulators. Therefore the term is

Fig. 1.--Simplified Flow Diagram for a Closed Economy



Richard Stone and Giovana Croft-Murray, <u>Social Accounting and Economic Models</u> (London: Bowes and Bowes, 1959), p. 12.

ambiguous in a functional sense. However, the term "consumption" sector refers to the particular function of consumers--their function only as consumers but not as producers and/or savers. Since "production" pays out the whole of its sales proceeds to "consumption" and since "consumption" divides its income between spending and saving, it follows that saving is identically equal to capital expenditure on real assets (or investment). The following two independent relationships summarize the above discussion:

$$Y \equiv C + S \tag{4.1}$$

$$S \equiv I \tag{4.2}$$

where:

Y = income paid to factors of production

C = consumers' expenditure on goods and services

S = saving (or income not consumed)

I = investment

(4.1) and (4.2) imply that

$$Y \equiv C + I$$

B. A Simple Analogue--Open Economy

Now, diagram 1 may be extended to exhibit an accounting structure for an open economy by adding a box which is called "rest of the world," that is the totality of other economies with which the economy in question is connected (Figure 2).

This diagram partially reproduces Figure 1. The new features are flows into and out of the "rest of the world" box, showing the expenditure on imports, and a "link" between "accumulation" and the "rest of the world," accounting for net lending (or borrowing) abroad due to disparity of imports and exports or other causes. The diagram represents a situation when the country under consideration has a favorable balance on current accounts which it lends to other countries.

The case of an open economy can be summarized by means of the following identities:

$$Y \equiv C + S \tag{4.4}$$

$$S \equiv I + L \tag{4.5}$$

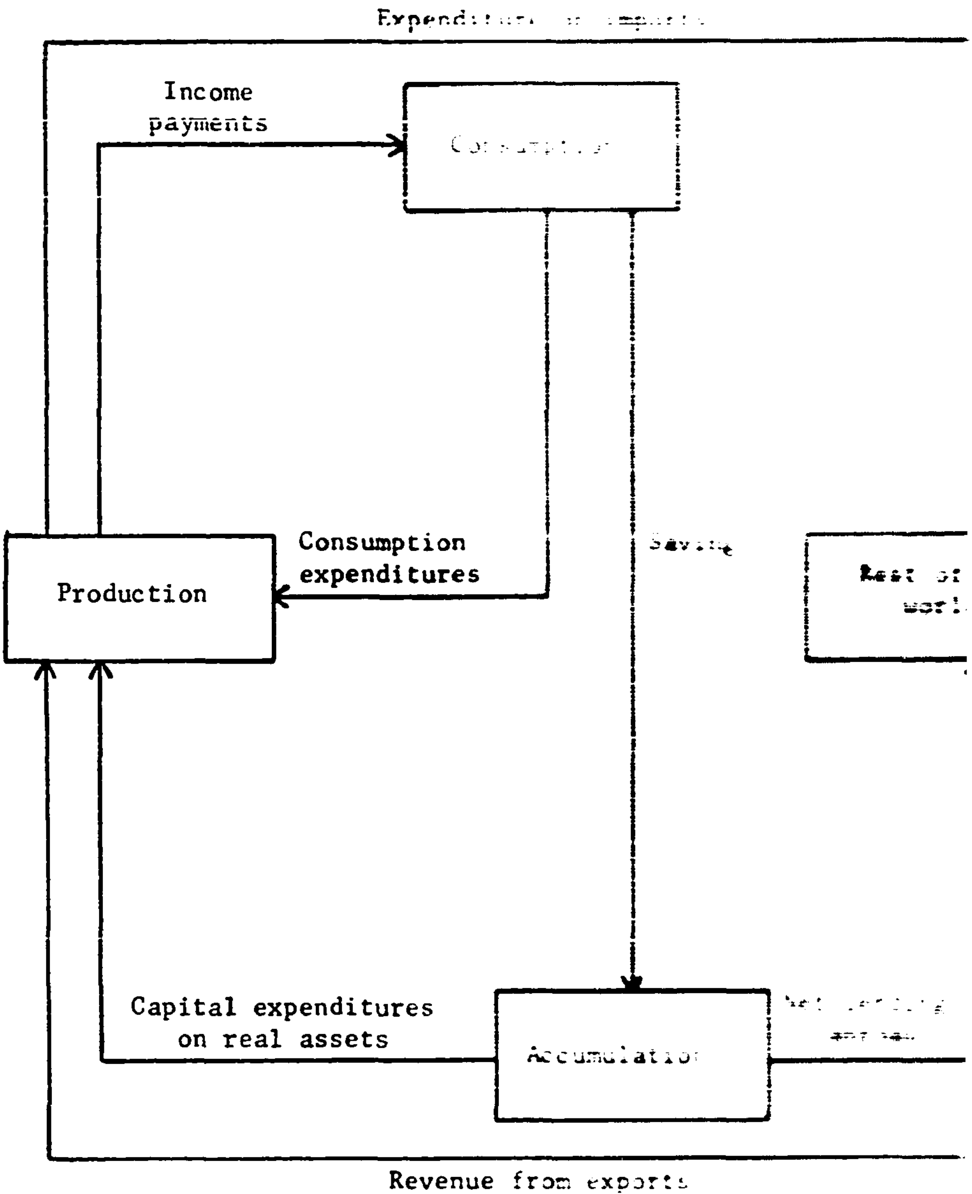
$$X \equiv M + L \tag{4.6}$$

where the new symbols X, M, and L designate exports, imports, and net lending abroad, respectively. Relation (4.5) indicates that the saving of the country finances both domestic investment and the amount which it lends abroad. Equation (4.6) shows that the value of exports of the given country is equal to the value of its imports plus the amount which it lends abroad.

Equations (4.4), (4.5), and (4.6) together imply

$$Y = C + I + X - M \tag{4.7}$$

Fig. 2.--Simplified [illegible] pen Economy



Richard Stone and Giovana Croft-Murray, [illegible]
Economic Models (London: Bowes and Bowes, [illegible]

economy in question is connected (Figure 2).

This diagram partially reproduces Figure 1. The new features are flows into and out of the "rest of the world" box, showing the expenditure on imports, and a "link" between "accumulation" and the "rest of the world," accounting for net lending (or borrowing) abroad due to disparity of imports and exports or other causes. The diagram represents a situation when the country under consideration has a favorable balance on current accounts which it lends to other countries.

The case of an open eco[illegible] can be summarized by means of the following identities: [illegible]

(4.4) [illegible]

(4.5) [illegible]

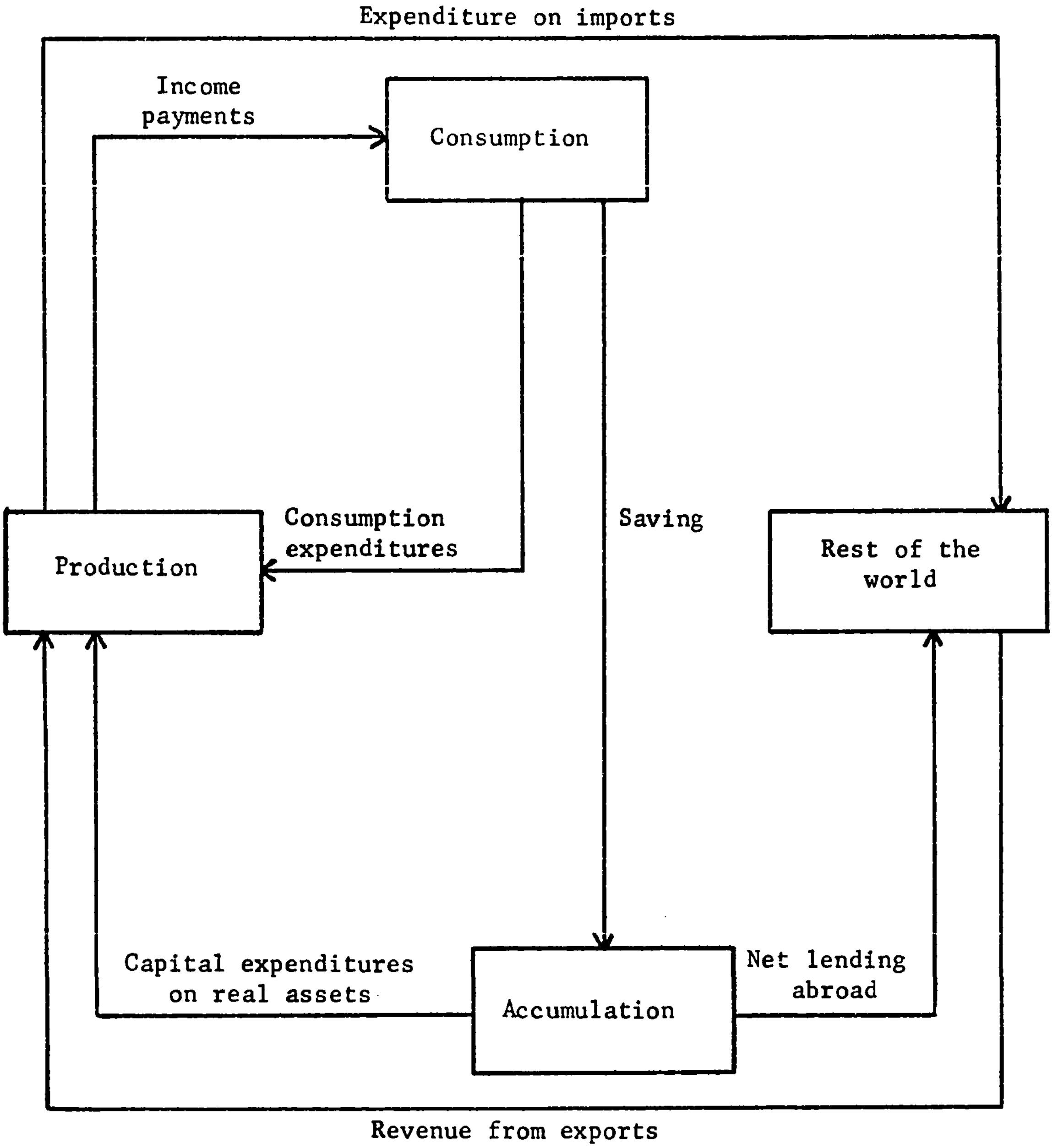
(4.6) [illegible]

where the new symbols [illegible]gnate exports, imports, and net lending abroad, respectively. Relation (4.5) indicates that the saving of the country finances both domestic investment and the amount which it lends abroad. Equation (4.6) shows that the value of exports of the given country is equal to the value of its imports plus the amount which it lends abroad.

Equations (4.4), (4.5), and (4.6) together imply

$$Y = C + I + X - M \tag{4.7}$$

Fig. 2.--Simplified Flow Diagram for an Open Economy



Richard Stone and Giovana Croft-Murray, Social Accounting and Economic Models (London: Bowes and Bowes, 1959), p. 15.

which shows that income payments are equal to consumption expenditures plus capital expenditures on real assets plus the excess of the value of exports over the value of imports.

C. A Complete Analogue

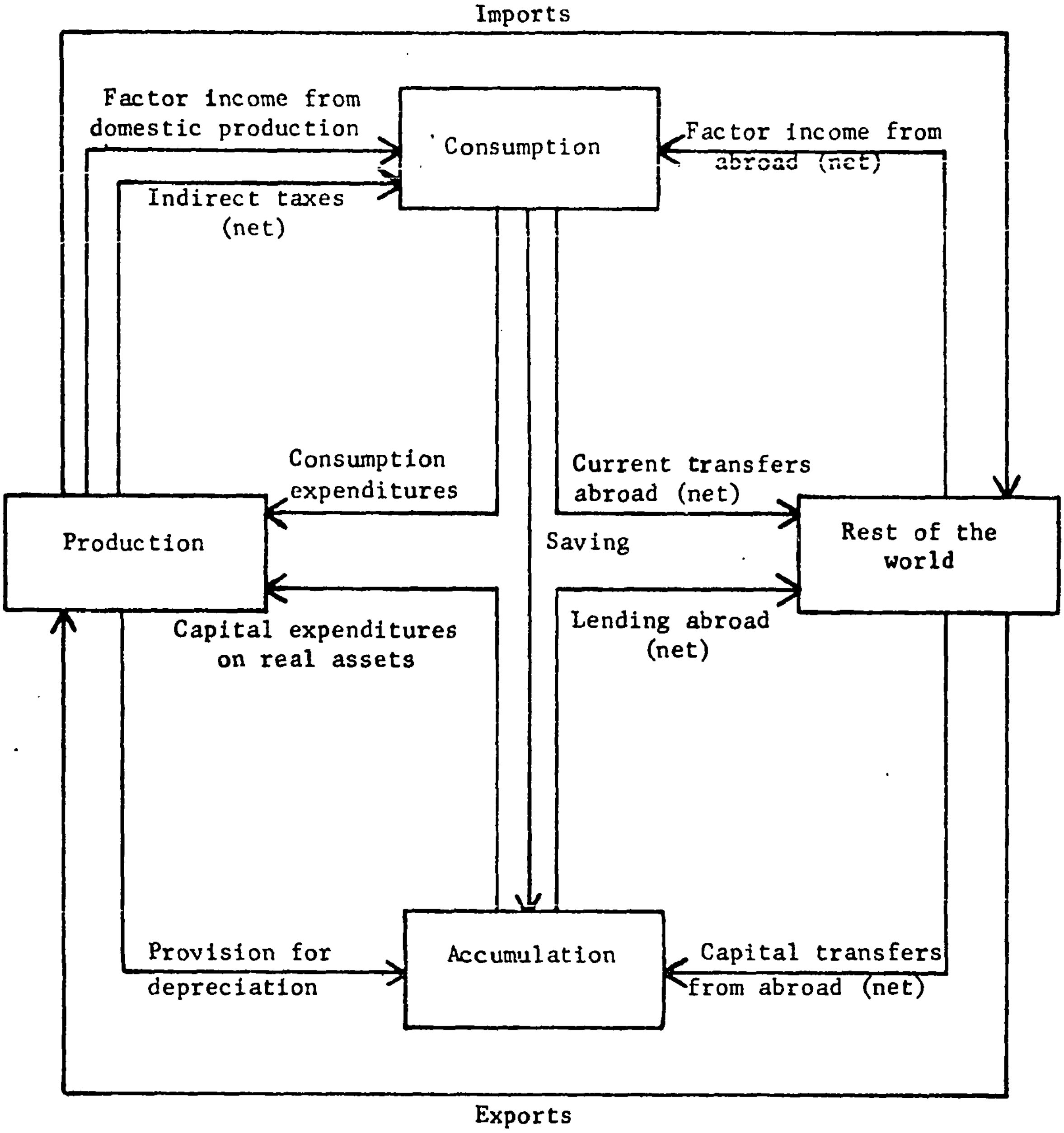
The accounting system can be made more realistic by including indirect taxes, current transfers abroad, capital transfers abroad, and depreciation allowances. This results in Figure 3, which should be interpreted in the same manner as Figures 1 and 2.

D. Matrix Representation

The diagrammatic representation followed so far is clear and useful because the number of accounts to be represented were small. If one tries to represent a large set of accounts in this way it is impossible to prevent the lines from crossing and the result is visual confusion. In such cases, the matrix presentation is most useful. Here the entries are set out in rows and columns in a rectangular table. The matrix format corresponding to Figure 3 is given in Table 1.

The figures in each row (indicated by *) measure incoming flows, while those in each column measure the outgoing flows. For example, the entries in the first row represent the arrows flowing into production and the entries in the first column represent the arrows flowing out of it in Figure 3. Hence, the first row and the

Fig. 3.--Complete Flow Diagram for an Open Economy



Richard Stone and Giovana Croft-Murray, Social Accounting and Economic Models (London: Bowes and Bowes, 1959), p. 19 (modified).

first column together constitute the production account. The only difference between the matrix and Figure 3 is that the two flows from "production" into "consumption"; namely, indirect taxes and factor income from domestic consumption, are consolidated into a single flow in the matrix form. Observe that the total in each row must be the same as the total in the corresponding column for they measure the same thing.

TABLE 1

A NATIONAL ACCOUNTING MATRIX

	Production	Consumption	Accumulation	Rest of the World	Row Totals
Production	o	*	*	*	*
Consumption	*	o	*	*	*
Accumulation	*	*	o	*	*
Rest of the World	*	*	*	o	*
Column Totals	*	*	*	*	. . .

Source:

Adapted from a table by Richard Stone and Giovana Croft-Murray, Social Accounting and Economic Models, London: Bowes and Bowes, 1959, p. 12.

It should be noted that the above accounting structure does not allow for classification of expenditure flows along institutional lines. Thus, the various accounts include the private as well as the government accounts of consumption and production.

2. From the National Income to the Input-Output Accounting

It was mentioned earlier in this chapter that the major difference between the Input-Output and National Income accounting systems is the degree of aggregation involved. In the following sections this proposition will be illustrated by means of manipulating the matrix introduced above (Table 1).

The matrices derived from Table 1 will prove helpful in illustrating the relationships between the two accounting systems under consideration. Once this relationship is explored, then it will be convenient to set out a new matrix, one that is more adaptable to the Input-Output models, in order to develop the basic accounting identities of this scheme.

A. Contrasting the Two Systems

To show more factual details about the accounts under consideration, each account in Table 1 may be subdivided into a number of constituent elements. This will result in a larger matrix, such as Table 2. This table exhibits the actual data for the United Kingdom in 1950.

TABLE 2

A Social Accounting Matrix for the United Kingdom in 1950
£ million

		Agriculture, forestry and fishing	*Mining and quarrying*	*Chemicals and allied trades*	*Metals, engineering and vehicles*	*Textiles, leather and clothing*	*Food, drink and tobacco*	*Other manufacturing*	*Building and contracting*	*Gas, electricity and water*	*Other production and trade**	*Other industries***	*Business and households appropriation*	*Government appropriation*	*Capital transactions*	*External*	*Row totals*
Agriculture, forestry and fishing .	*Goods and services* . .	0	0	3	0	28	563	14	0	0	1	0	468	8	5	9	1099
Mining and quarrying . .		6	0	110	42	19	14	23	27	127	56	0	99	4	−9	45	566
Chemicals and allied trades .		77	24	0	104	30	59	52	59	7	88	0	215	51	−7	156	915
Metals, engineering and vehicles		56	50	45	0	48	33	25	160	50	249	0	260	217	807	1032	3084
Textiles, leather and clothing .		10	5	15	41	0	13	92	3	1	27	0	828	3	−80	533	1458
Food, drink and tobacco . .		116	0	10	0	1	0	0	0	0	15	0	2170	16	40	129	2497
Other manufacturing . .		41	6	38	200	55	71	0	181	15	70	0	198	95	−22	167	1115
Building and contracting . .		30	21	8	22	15	8	4	0	2	73	0	243	150	661	2	1239
Gas, electricity and water .		4	9	13	60	13	14	32	9	0	88	0	230	28	39	4	543
*Other production and trade** .		100	30	105	445	120	145	80	135	65	0	0	2592	293	123	543	5076
*Other industries*** . . .		0	0	0	0	0	0	0	0	0	0	0	1745	1206	−67	115	2999
Business and households appropriation	*Wages and salaries* . .	264	359	149	1405	433	247	465	503	143	2317	1264	0	0	0	0	7503
	Profits, interest and rent .	332	33	93	441	161	226	112	102	0	1129	70	0	0	0	337	3036
	Public debt interest . .	0	0	0	0	0	0	0	0	0	0	0	0	551	0	0	551
	Other current transfers . .	0	0	0	0	0	0	0	0	0	0	0	0	754	0	0	754
Government appropriation .	*Current transfers (taxes less subsidies)* . . .	−44	3	70	11	11	678	11	7	23	313	504	2251	0	0	0	3533
Capital transactions . . .	*Depreciation* . . .	54	15	31	94	36	30	36	14	107	284	297	0	0	0	0	998
	Saving	0	0	0	0	0	0	0	0	0	0	0	350	417	0	0	767
	Capital transfers (net) .	0	0	0	0	0	0	0	0	0	0	0	0	0	0	167	167
External	*Goods and services* . .	53	11	225	218	468	396	168	39	1	366	864	0	0	0	0	2809
	Current transfers (net) . .	0	0	0	0	0	0	0	0	0	0	0	−5	45	0	0	40
	Lending (net) . . .	0	0	0	0	0	0	0	0	0	0	0	0	0	440	0	440
Column totals		1099	566	915	3084	1458	2497	1115	1239	543	5076	2999	11944	3533	1932	3239	..

* Transport and communication, distributive trades, insurance, banking and finance, and other services.
** Public administration and defence, public health and educational services, ownership of dwellings, domestic services to households, and services to private non-profit-making bodies.

Source: Adapted from a table by Richard Stone and Giovana Croft-Murray, Social Accounting and Economic Models, London: Bowes and Bowes, 1959, p. 14.

The first eleven row-and-column pairs represent the production accounts of the eleven sectors among which the whole of British production is allocated. For example, the third row-and-column pair relates to productive activity in chemicals and allied trades.

The entries in each row represent the distribution of the product of each industry among all other industries and the various kinds of final uses. Looked at from the revenue side, these entries represent the revenues of a given sector originating in other sectors of the economy. For example, reading across the third row, the receipts of chemicals and allied trades from agriculture, forestry, and fishing were 77 million pounds and those from mining and quarrying were 24 million pounds in 1955, etc. The entries in each column show the costs of producing the total value of the given sector. For example, the entries in the third column indicate the amounts paid by the third industry to various other industries for the purchase of produced inputs of the sector. Hence, each column reflects the cost structure of the related industry.

If the first eleven production accounts (that is, rows and columns) in Table 2 are consolidated, the national account for production is obtained.

The next two row-and-column pairs, labeled "business and household appropriation" and "government appropriation," represent consumption accounts. If these two accounts are consolidated, the national account for consumption is obtained.

The last two accounts are already in consolidated form. The fourteenth relates to the capital transactions of all transactors in the economy and represents the national accounts for accumulation; and the fifteenth relates to their external transactions, that is, their transactions with the rest of the world.

It should be pointed out that Table 2 is being used merely for illustrating the relationships between the National Income and Input-Output accounting systems. The data, although based on official British estimates, have been modified in accordance with a large number of assumptions in order to be presented in the form given above.[6] The data are not recommended for actual quantitative analysis of the British economy.

Note that the format of Table 1 is nothing more than a particular consolidation of that of Table 2. By a different consolidation of the accounts in Table 2, another matrix can be obtained which enables one to concentrate on the production account to the exclusion of all other elements in the system. This results in an input-output matrix, and it is set out in Table 3. It is obtained from Table 2 by consolidating the last four accounts and leaving out the row and column totals.

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[6]Stone and Croft-Murray, pp. 40-41.

TABLE 3

AN INPUT-OUTPUT MATRIX FOR THE
UNITED KINGDOM IN 1950
(millions of pounds)

	Agriculture, forestry and fishing	Mining and quarrying	Chemicals and allied trades	Metals, engineering and vehicles	Textiles, leather and clothing	Food, drink and tobacco	Other manufacturing	Building and contracting	Gas, electricity and water	Other production and trade	Other industries	All other accounts consolidated
Agriculture, forestry and fishing .	0	0	3	0	28	563	14	0	0	1	0	490
Mining and quarrying	6	0	110	42	19	14	23	27	127	56	0	142
Chemicals and allied trades .	77	24	0	104	30	59	52	59	7	88	0	415
Metals, engineering and vehicles	56	50	45	0	48	33	25	160	50	249	0	2368
Textiles, leather and clothing .	10	5	15	41	0	13	92	3	1	27	0	1281
Food, drink and tobacco	116	0	10	0	1	0	0	0	0	15	0	2355
Other manufacturing .	41	6	38	200	55	71	0	181	15	70	0	438
Building and contracting .	30	21	8	22	15	8	4	0	2	73	0	1056
Gas, electricity and water . .	4	9	13	60	13	14	32	9	0	88	0	301
Other production and trade .	100	30	105	445	120	145	80	135	65	0	0	3851
Other industries . .	0	0	0	0	0	0	0	0	0	0	0	2999
All other accounts consolidated .	659	421	568	2170	1159	1577	793	665	276	4409	2999	0

Source:

Adapted from a table by Richard Stone and Giovana Croft-Murray, <u>Social Accounting and Economic Models,</u> London: Bowes and Bowes, 1959, p. 15.

More formally, let M_{qxq} represent the matrix in Table 2, where the subscript q x q denotes that the matrix has p rows and q columns. Then each particular consolidation may be thought of as the result of a matrix multiplication of the form

$$G^1_{nxp} \; M_{qxq} \; G^2_{qxr} = N_{nxr}$$

where G^1 and G^2 are two grouping matrices[7] that consolidate the original $q \times q$ matrix to get a new $n \times r$ matrix N. Formally, there are many such matrices because there are many possible grouping matrices G^1 and G^2. But many of the formally possible consolidations are not useful. The grouping matrices assume such structures that would enable them to consolidate M according to a definite conceptual framework. National Income and Input-Output are two such frameworks. Naturally, other conceptual frameworks and, therefore, other pairs of grouping matrices could be developed.

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[7]A matrix G is called a grouping matrix relative to another matrix M if GM or MG (assuming that multiplication is defined) have smaller dimensions than M and if their elements are derived from the elements of M by omission or summation and by no other operation. For example, consider:

$$\begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \\ a_{41} & a_{42} & a_{43} \end{bmatrix} \begin{bmatrix} a_{11} + a_{21} & a_{12} + a_{13} & + a_{23} \\ a_{31} & a_{32} & a_{33} \\ a_{41} & a_{42} & a_{43} \end{bmatrix}$$

Here the premultiplication of a matrix by another has led to the omission of its third row and to conversion of the elements of its first row from a_{1j} to $a_{1j} + a_{2j}$; that is, the first row of the new matrix is the vector sum of the first two rows of the first matrix. Here the matrix on the left is an example of a grouping matrix.

Just as premultiplication (on the left) of a matrix by a grouping matrix operates on its rows, postmultiplication (on the right) of it by another grouping matrix operates on its columns.

Therefore, in principle, there exists a system of social accounts that includes the input-output accounts and the national accounts as two of its particular subsystems. This comprehensive social accounting system could be developed if its usefulness justified the cost. Undoubtedly there would be many statistical problems, both conceptual and practical, but these would not be essentially different from those encountered in the development of the existing accounts.

Such a comprehensive social account is not likely to develop prior to the development of an analytical system which would serve as a theoretical counterpart to it. But its usefulness in the unification of various social accounts does not depend on whether or not it is empirically implemented. The concept is useful, as noted above, as a means of a formal treatment of various social accounts in a unified manner.

B. Basic Input-Output Identities

Table 3 is a very simple example of input-output matrices designed to show the manner in which the Input-Output and National Income frameworks are related. For the development of the fundamental identities and a detailed description of the Input-Output framework, a more general format is desirable. Table 4 provides this.

Each row of Table 4 shows the pattern of allocation of the output of a given industry among different uses. In monetary terms, the entries of a given row indicate the receipts of the industry in that row from various sources where its product is sold. It should be noticed that the table distinguishes between "intermediate use" and "final use" of a product. These concepts are essentially the familiar ones utilized in the National Income accounting where a good is defined as final if it is bought not for purpose of reselling or further processing; and a good is intermediate if it is not final. In later discussion where a "closed" Leontief system is discussed, it will be seen that there is nothing inherent about defining certain categories of expenditure in the economy as final; and that it depends on the model under consideration whether, for example, consumption is to be classified as a final-use or as an intermediate-use item.

Table 4 also exhibits a distinction between "produced" and "primary" inputs, corresponding to the "intermediate" and "final" products on the output side.

An input is called primary if it is not produced within the system. For example, if the supply of labor is treated as a datum rather than a variable, then labor is a primary input. An input which is not primary is a produced input.

The entries in a given column record the cost structure of the given industry. For example, the entries in the first column indicate the values of various inputs utilized by the industry during the period that its output is measured.

TABLE 4

INTERINDUSTRY ACCOUNTING SYSTEM

	Purchasing Sectors									
	Intermediate Use		Final Use						Supply	
	Sectors $1 \ldots j \ldots n$	Total Intermediate Use	Investment	Consumption	Government	Exports	Total Final Use	Total Supply = Total Use	Imports	Production
Producing Sectors 1	$x_{11} \ldots x_{1j} \ldots x_{1n}$	W_1	I_1	C_1	G_1	E_1	Y_1	Z_1	M_1	X_1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	$x_{i1} \ldots x_{ij} \ldots x_{in}$	W_i	I_i	C_i	G_i	E_i	Y_i	Z_i	M_i	X_i
⋮	(Quad. II)	⋮	(Quad. I)				⋮	⋮	⋮	⋮
n	$x_{n1} \ldots x_{nj} \ldots x_{nn}$	W_n	I_n	C_n	G_n	E_n	Y_n	Z_n	M_n	X_n
Total Produced Inputs	U_1 U_j U_n									
Primary Inputs (Value Added)	$V_1 \ldots V_j \ldots V_n$ (Quad. III)		V_I (Quad. IV)	V_C	V_G	V_E		V		V
Total Production	$X_1 \ldots X_j \ldots X_n$		I	C	G	E	Y	Z	M	X

Source: Hollis B. Chenery and Paul G. Clark, Interindustry Economics (New York: John Wiley and Sons, Inc., 1967).

Quadrant I contains the final use of produced commodities and services, broken down by major types of use; namely, investment, consumption, government, and exports.

Quadrant II constitutes the main part of the interindustry accounts. The i-th row of this quadrant $(x_{i1}, x_{i2}, \ldots, x_{in})$ shows how much of the output of the i-th industry is used as input by industries 1, 2, . . . , n, respectively. W_i is that part of the output of the i-th industry which is used as input by all other industries, that is:

$$(4.8) \qquad W_i = \sum_{j=1}^{n} x_{ij}, \qquad (i = 1, \ldots, n)$$

The j-th column of quadrant II $(x_{1j}, x_{2j}, \ldots, x_{nj})$ shows how much of the outputs of industries 1, 2, . . . , n is used up by the j-th industry as inputs. U_j is the total value of produced inputs used up by the j-th industry:

$$(4.9) \qquad U_j = \sum_{i=1}^{n} x_{ij}, \qquad (j = 1, \ldots, n)$$

Quadrant III shows the value of primary inputs utilized by each industry. X_j measures the total revenue (or total value of the output) of the j-th industry. The total receipts of the j-th industry is paid out as costs to produced or to primary inputs.[8] That is:

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[8]This is only true if the j-th sector does not engage in saving or investing activities. This question will be dealt with when the

$$(4.10) \qquad X_j = V_j + U_j, \qquad (j = 1, \ldots, n)$$

or

$$(4.11) \qquad V_j = X_j - U_j, \qquad (j = 1, \ldots, n)$$

Equation (4.11) states that V_j is equal to the difference between the value of output and the cost of inputs produced outside the given establishment. In other words, V_j is the value added in production by the j-th sector. Note that quadrant III does not distinguish between different types of primary inputs. The degree of disaggregation in this quadrant varies considerably in empirical input-output tables.

Quadrant IV contains the direct input of primary factors to final use, of which the main examples are government employment and domestic service. These transactions do not enter into most interindustry models, but they should be recorded to make the total consistent with national aggregates.[9]

Total supply of each commodity consists of the sum of domestic production and imports (negative for exports). That is:

$$(4.12) \qquad Z_i = X_i + M_i, \qquad (i = 1, \ldots, n)$$

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distinction between static and dynamic Leontief systems are discussed in later chapters.

[9] For a discussion of this point see: Hollis B. Chenery and Paul G. Clark, Interindustry Economics, New York: John Wiley and Sons, Inc., 1967, p. 17.

or

$$X_i = Z_i - M_i , \qquad (i = 1, ... , n) \tag{4.13}$$

where Z_i, X_i, and M_i are the total supply, total output, and total imports of the i-th sector, respectively.

Let Z, X, and M denote the values of total supply (or use), total domestic production, and total imports, respectively. Then the following identities must hold:

$$X = Z - M \tag{4.14}$$

$$X = \sum_{i=1}^{n} X_i = \sum_{j=1}^{n} X_j \tag{4.15}$$

$$Z = \sum_{i=1}^{n} Z_i \tag{4.16}$$

$$M = \sum_{i=1}^{n} M_i \tag{4.17}$$

This concludes the development of the fundamental identities of the two accounting systems under consideration. Throughout the discussion, no attempts were made toward defining such concepts as "sector," "industry," and "establishment." These concepts must be defined operationally in the sense that their definition must made it clear what facts belong and what facts do not belong to each category. Otherwise, the empirical counterpart of the above theoretical schemes cannot be constructed.

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Once a basic classification of facts is achieved, that is, once one set of rules of correspondence between groups of facts and theoretical empty boxes (or categories) is established, then it is of interest to explore the effect of shifting facts from some categories and entering them in other categories. But, as it will be discussed in great detail in later chapters, the questions related to reclassification almost unavoidably involves the purpose of the analysis that uses the facts; and it is futile to attempt to establish classificatory schemes in abstraction from the purpose (or purposes) that the model is designed to serve. Therefore, a precise definition of concepts of "industry," and "sector" has to await a rather detailed consideration of the structure of the theoretical systems involved. This is the task of a later chapter. In this chapter a general view of the purposes of each system of analysis under discussion is of interest because it relates to the scope of each of the two social accounting systems being studied here.

C. A Note on Scope

It has been seen that the input-output has a larger scope than the national income accounting. This variation in scope from one system to another reflects the differences in the purposes that each system is designed to serve. This does not mean that all the uses that a social accounting system such as the input-output is put to must be known prior to the development of such a system. This would be a mechanical and incomplete view of the process. In reality, there is a continual dynamic interaction and an unceasing chain of feedbacks between the scope of a theoretical system and that of its empirical counterpart.

As the theoretical system evolves, as new aspects of reality are brought within the realm of theoretical analysis, it may be necessary to modify, enlarge, or even completely restructure the organization of the empirical content of the theoretical model.

On the other hand, a theoretical model may be forced to compromise its scope due to impossibility of measurement and observations in relation to a portion of the related factual studies. This may be due to technical and statistical difficulties or due to prohibitive costs. In this case, the technical and cost aspects of the empirical work implied by a given theoretical model forces the model to assume a less ambitious scope which would be more in line with the available technical know-how and financial resources.

Since the purpose of a model is such an important determining factor in relation to the scope of its empirical counterpart, it is desirable to attempt to state explicitly the main purposes of the theoretical systems that correspond to the two social accounting systems being investigated. The undertaking will necessarily be schematic, since a discussion in this area can very easily become unmanagable.

The theoretical system that corresponds to the national income accounting is the Keynesian framework as modified and developed by many economists since Keynes. The theoretical system behind input-output accounting is the input-output analysis as dev developed by Leontief and many other economists who worked independently or with him on the Harvard Economic Project. In this section a schematic overview of the purposes of each of these two theoretical systems will be presented.

i. Keynesian system. National accounts have developed from earlier estimates of national income. The aim of these estimates was to produce a total figure for the national income, "usually interpreted as a measure of welfare."[10] "The influence of the earlier estimates on today's national accounts is still manifest, e.g., in the statistician's strong interest in aggregates, in discussion on 'how national income is correctly defined,' and so on."[11]

The national income aggregates were, from the early days of their development, considered important as tools for registering the record of the economy:

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[10] Aukrust, p. 205.

[11] Ibid.

> . . . National income estimates when constructed on a fairly comparable basis for a period of years provide a composite record of the economic activity of a country that affords a broader view and better understanding of its economic history than any other series of general statistics.[12]

But it is economic theory that has provided the strongest stimulus to the development of national accounting. Aukrust mentions three tendencies with this regard:[13]

(a) The shifting of interest from microeconomic to macroeconomic theory in which aggregates like national income, total consumption, etc., play a major role.

(b) The increasing interest in and understanding of macroeconomic repercussions, which has led to intensive studies of the process of economic circulation.

(c) The application of econometric methods to macroeconomic problems. Aukrust adds that recent problems of economic policy, related to full employment and national budgeting, have also given an impulse to national accounting work. "On the international level the need for international comparisons is strongly felt."[14]

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[12]Robert F. Martin, National Income in the United States: 1799-1938, New York: National Industrial Conference Board, Inc., 1939, p. 1.

[13]Aukrust, p. 205.

[14]Ibid.

The development of Keynesian macro-theory has provided the analytical tools towards the understanding of and policy recommendation with regard to four fundamental aspects of the economy: price stability, full employment, optimum growth, and international equilibrium.

In relation to each of the four broad problems, it is necessary to develop a general quantitative index. As to any disaggregation within each of these indexes, the theory fails to provide any direction. Consequently, the statistician relies on traditional practices, disaggregating the general index into a few components based on such characteristics as the institutional categories--private, public, state, local, and Federal government--or on type of commodity, such as consumers' durable, nondurables, plant and equipment, and goods in inventory. Price indexes may be developed for wholesale and retail prices of consumer goods, capital goods, industrial goods, and agricultural goods.

But the type and the degree of disaggregation within each index is for the most part arbitrary, lacking a logical framework that would instruct a specific structure of disaggregation. Therefore, the scope of accounting and measurement against a background of macroeconomic theory as it stands today is specified only within very broad limits, leaving ample room for arbitrariness within these boundaries. This stands in sharp contrast to the input-output

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[12] Robert [illegible] in the United States: 1799-1938, New [illegible] Conference Board, Inc., 1939, p. 1.

[13] Aukrust, [illegible]

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ii. Input-output analysis. There are several purposes for constructing the input-output accounts, and different purposes require different types of information to be registered in the accounts. Sandee distinguishes between three major purposes:[15] the derivation of aggregates, such as national income; the derivation of a short-term model of the economy; and the derivation of a long-term (or ("structural") model.

The derivation of aggregates from the input-output account rather than by direct estimation method of the national income statistician may seem superfluous. Why should one try to estimate interindustry flows that are destined to be "netted out" in the final presentation of the aggregates. "However, the fitting of each flow into the supply pattern of one industry and into the consumption pattern of another often brings to light unexpected deficiencies in either of these patterns. When the full matrix has been assembled, the output and input of each industry have been subjected to such severe scrutiny that the statistician may well feel more confident about them."[16]

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[15] J. Sandee, in Barna (ed.), p. 219.

[16] Ibid.

Short-term models of a national economy describes how the main economic variables move in relation to one another. Very few models contain branch-wise detail, though some specifically mention agriculture or construction. Input-Output accounts may serve (a) to supply estimates for the coefficients of the aggregate models mentioned above, and (b) to supply coefficients for more detailed models. In the short-run models, a distinction is necessary between constant and variable inputs because in the short-run inputs cannot be expected to move in proportion to outputs.

Long-run models need not distinguish constant from variable inputs for in the longer run, productive capacity will be adapted to the level of output, and over longer periods inputs that were constant in the short run will move in proportion to output. For the construction of input-output accounts, this implies that inputs which were constant in the short run, and "could therefore more or less be neglected for short-term models, must be taken just as seriously as straightforward raw material inputs and the like."[17]

The distinction between major purposes in the input-output analysis must be kept in mind because sometimes they will point to different conclusions. From the accounting point of view, it is technically possible to construct a system of accounts containing the

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[17] _Ibid._, p. 220.

information needed for all three of them. Statistically, the refinements needed for one purpose will often be superfluous for the other. The distinction between accounting and statistical problems is not absolute: accounting problems will have to be solved in such a way as to cause least trouble to the statistician, i.e., requiring the smallest number of additional, more or less crude estimates.

The above discussion proceeded along general lines. More specifically, the input-output has been applied to many different areas of economic analysis. To mention but a few: economic forecasting, identification of the structure of an economy in various stages of growth, measurement of the past growth and of the potential for future growth, identification of bottlenecks in an economy as an emergency such as was necessitates a radical change in the composition of its final demand, forecasting the nature and pace of technological development within the economy, and comparative studies of the structure of the existing world economies.

The core of the input-output accounting is the construction of the interindustry flow matrix which is the basis for the derivation of the input-output coefficients. The matrix of these coefficients, reflecting the technological interrelation among the various sectors of the economy, constitutes a highly disaggregated production function for the economy.

The degree as well as the type of disaggregation in input-output accounting is completely specified by the theoretical model behind it. Hence, there is little room left for arbitrariness in the actual construction of the accounts.

3. Summary

This chapter was concerned with the presentation of the n national income and input-output accounting. These two were introduced within a unified framework in order to emphasize their close relationship. It was shown that, as a social accounting scheme, the national income accounting is a much less ambitious system than the input-output accounting. This feature was studied in relation to the purpose of each system, and it was proposed that the purpose at hand was a primary determinant of the scope and nature of data collection and classification. This point will be studied further in relation to the classification and aggregation problems in a later chapter.

CHAPTER V

THEORETICAL SCHEMES RELATED TO NATIONAL INCOME AND INPUT-OUTPUT ACCOUNTING

The two social accounting systems presented in the preceding chapter are based on two separate theoretical frames: Keynesian analysis and Leontief's input-output analysis. In this chapter these two theoretical systems will be introduced within a static framework. Consideration of the dynamic extensions of the two systems is of no direct interest to the objective of this study, namely, the presentation and analysis of the aggregation problem. The choice of a less exhaustive scope by means of limiting the study to a static framework provides an opportunity to cope with some specific problems in more detail than would otherwise be permissible.

The assumptions related to the production function in each system is given a particularly detailed treatment because of the importance of this area, particularly in the case of input-output analysis.

The chapter will be concluded with a set of comparisons on a general level between the two systems.

1. Keynesian System

Perhaps the most elegant formulation of the Keynesian system is that provided by Paul Samuelson.[1] In this formulation, Samuelson concentrates only on the "fundamental relationships stressed by Keynes."[2] Ames remarks that "we cannot be sure" that Samuelson's formulation represents the Keynesian system because "Keynes's book[3] is, in many places, very obscure."[4]

It is true that Samuelson's formulation has a more limited scope than the formulations that are popularized in macroeconomic texts. Specifically, the latter usually include a production function in the model, a relationship which is left out by Samuelson (perhaps) as being incidental.

Samuelson's formulation, in spite of its more limited scope, exhibits all the characteristic features of the Keynesian system and its method of analysis. Therefore, this formulation will be presented

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[1] Paul A. Samuelson, Foundations of Economic Analysis, Cambridge: Harvard University Press, 1963, pp. 276-278.

[2] Ibid.

[3] J. M. Keynes, General Theory of Employment, Interest and Money, London: Bowes and Bowes, 1935.

[4] Edward Ames, Introduction to Macroeconomics Theory, New York: Holt, Rinehart and Winston, 1968, p. 54.

here. However, since a discussion of the production function (implicit or explicit) in the Keynesian scheme is vital for the purpose of comparison with Leontief's system, the popular version of the Keynesian system will be briefly outlined after a rather detailed examination of the Samuelson formulation.

A. Samuelson's Formulation

The following discussion essentially repeats Samuelson's except for the summarizing of the model by means of matrix notation and the "filling in" of the mathematics in a few places.

The three fundamental relationships stressed by Keynes are (1) the consumption function relating consumption (and hence savings-investment) to income and, for generality, to interest rate as well; (2) the marginal efficiency of capital relating net investment to the interest rate and to the level of income;[5] (3) the liquidity preference schedule relating the existing amount of money to the interest rate and the level of income.

These schedules can be formulated as follows:

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[5] No relationship is assumed between the level of capital equipment and the marginal efficiency of capital because the Keynesian analysis is concerned with the short run and in the short run the level of capital equipments can be treated as fixed.

$$(5.1) \qquad y = [C(r, y) + \alpha] + I$$

$$(5.2) \qquad I = F(r, y) + \beta$$

$$(5.3) \qquad L(r, y) = M$$

where r, y, I stand respectively for the rate of interest, income, and investment; C, F, L stand respectively for the consumption function, the marginal-efficiency-of-capital schedule, and the liquidity-preference schedule. M stands for the existing amount of money, taken as a parameter; α is a shift parameter for the consumption function and β is a shift parameter for the marginal-efficiency-of-capital schedule.

Equation (5.1) expresses the equilibrium condition that in a closed economy with no government, the total income must equal the sum of consumption and ex ante investment. This is the equilibrium condition in theproduct market. Equation (5.2) is a behavioral relation, expressing the level of investment as a function of the interest rate and the level of income. Finally, equation (5.3) sets the amount of money demanded equal to the supply of money, expressing the equilibrium condition in the money market.

The three relations above can determine the three unknowns r, y, and I in terms of the three parameters α, β, and M:

$$(5.4) \qquad \begin{aligned} r &= r(\alpha, \beta, M) \\ y &= y(\alpha, \beta, M) \\ I &= I(\alpha, \beta, M) \end{aligned}$$

The objective of the model is to show how the unknowns will change as a result of changes in the parameters (data). Therefore, the sign of the following partial derivatives are of interest.

$$(5.5) \qquad \begin{aligned} &\frac{\partial r}{\partial \alpha}, \ \frac{\partial y}{\partial \alpha}, \ \frac{\partial I}{\partial \alpha} \\ &\frac{\partial r}{\partial \beta}, \ \frac{\partial y}{\partial \beta}, \ \frac{\partial I}{\partial \beta} \\ &\frac{\partial r}{\partial M}, \ \frac{\partial y}{\partial M}, \ \frac{\partial I}{\partial M} \end{aligned}$$

The expressions in (5.5) can be found by differentiating totally the relations (5.1), (5.2), and (5.3) and evaluating these relations. It is convenient to transpose the relations and express them in the following form:

$$(5.6) \qquad C(r, y) - Y + I = -\alpha$$

$$(5.7) \qquad F(r, y) - I = -\beta$$

$$(5.8) \qquad L(r, y) = M$$

Differentiating these totally, one obtains:

$$(5.9) \qquad C_r \, dr + (C_y - 1) \, dy + dI = -d\alpha$$

$$F_r\,dr + F_y\,dy - dI = -d\beta \tag{5.10}$$

$$L_r\,dr + L_y\,dy = dM \tag{5.11}$$

Expressing (5.9), (5.10) and (5.11) in matrix notation gives:

$$\begin{bmatrix} C_r & C_{y-1} & 1 \\ F_r & F_y & -1 \\ L_r & L_y & 0 \end{bmatrix} \begin{bmatrix} dr \\ dy \\ dI \end{bmatrix} = \begin{bmatrix} -d\alpha \\ -d\beta \\ dM \end{bmatrix} \tag{5.12}$$

To evaluate $\frac{\partial r}{\partial \alpha}$, let $dy = dI = d\beta = dM = 0$; that is, hold all the parameters not under investigation constant and then solve the system (5.12) for dr. Applying Cramer's rule:

$$dr = \frac{\begin{vmatrix} -d\alpha & C_{y-1} & 1 \\ 0 & F_y & -1 \\ 0 & L_y & 0 \end{vmatrix}}{\Delta} = -d\alpha . \frac{L_y}{\Delta} \tag{5.13}$$

where

$$\Delta = \begin{vmatrix} -d\alpha & C_{y-1} & 1 \\ -d\beta & F_y & -1 \\ dM & L_y & 0 \end{vmatrix}$$

$$= L_y(F_r + C_r) + L_r(1 - C_y - F_y) \tag{5.14}$$

From (5.13) it is seen that:

$$\frac{dr}{d\alpha} = -\frac{L_y}{\Delta} \tag{5.15}$$

Since some parameters are being kept constant, the notation $\frac{\partial r}{\partial \alpha}$ is appropriate:

$$\frac{dr}{d\alpha} = -\frac{L_y}{\Delta}$$

By a similar method, all the other partial derivatives can be evaluated. They are:

$$\frac{\partial r}{\partial \alpha} = -\frac{L_y}{\Delta}, \quad \frac{\partial Y}{\partial \alpha} = \frac{L_r}{\Delta}, \quad \frac{\partial I}{\partial \alpha} = \frac{F_y L_r - F_r L_y}{\Delta}$$

$$\frac{\partial r}{\partial \beta} = -\frac{L_y}{\Delta}, \quad \frac{\partial Y}{\partial \beta} = \frac{L_r}{\Delta}, \quad \frac{\partial I}{\partial \beta} = \frac{(1 - C_y) L_r + C_r L_r}{\Delta} \tag{5.16}$$

$$\frac{\partial r}{\partial M} = \frac{1 - C_y - F_y}{\Delta}, \quad \frac{\partial Y}{\partial M} = \frac{F_r + C_r}{\Delta},$$

$$\frac{\partial I}{\partial M} = \frac{F_y(F_r + C_r) + (1 - C_y \; F_y)F_r}{\Delta}$$

"On the basis of a priori, intuitive, empirical experience"[6] the following assumptions are made:

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[6]Samuelson, Foundations . . . , p. 277.

(5.17) $$C_y > 0\,,\ F_y > 0\,,\ F_r < 0\,,\ L_y > 0\,,\ L_r < 0$$

while

$$C_r \gtreqless 0$$

and is usually considered to be of minor quantitative importance.

The assumptions (5.17) state that consumption, investment, and liquidity preference are directly related to income and that investment and liquidity preference are inversely related to the rate of interest.

It can be seen that the assumptions (5.17) are not sufficient to determine the sign of Δ in (5.14). Furthermore, the signs of some of the numerators in (5.16) are indeterminate. "On the basis of deductive analysis along strictly statical lines nothing can be inferred"[7] concerning the sign of Δ. "If we are to derive useful theorems, we must clearly proceed to a consideration of a more general dynamic system which includes the stationary Keynesian analysis as a special case."[8]

Samuelson proceeds to show two alternative ways for this sort of development. These further developments are not of interest in the present discussion.

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[7] Ibid., p. 278.

[8] Ibid.

The above presentation of the Keynesian system, in spite of its rather abstract formulation and limited scope, does illustrate the spirit of this sort of analysis.

The analysis is based on a few general propositions about the way in which a set of economic aggregates or variables--income, investment expenditure, interest rate, etc.--are interrelated. The simplicity of the model stands in sharp contrast to the complexity of the real economic system. This simplicity is achieved through the engagement in heroic aggregation of economic quantities. It also reflects the limited objective of the Keynesian analysis, namely, the determination of the most immediate factors that influence, in the short run, the level of income.

The Keynesian system abstracts from the micro-processes, the unending chain of actions and reactions through which the economic organism performs its functions. It observes the end result of these processes and aims at discovering functional relationships among these end-result aggregates with no particular interest in the micro-processes that lie behind such functional relationships. Because of this preoccupation with aggregates (of the highest degree), the system inherently possesses a relatively low "fact-absorbing capacity." On the analytical side, the system divorces macroeconomics from microeconomics, discounting the significance of microeconomics in the understanding of the behavior and magnitude of the macroeconomic variables. This amounts to nothing less than a compartmentalization of economic theory into two unrelated areas.

The above statements should not be taken as a critical evaluation of the Keynesian system. No theoretical system can be evaluated in abstraction from its announced purpose. The Keynesian system is a limited system for a limited objective. More will be said of this point in a later chapter when the question of empirical implementation of theoretical systems is discussed.

The model as presented above is a general equilibrium mod model which simultaneously determines the values of the endogenous variables in terms of the exogenous variables and parameters.[9] The method of the Keynesian analysis is comparative statis,[10] that is, the "comparison of different equilibrium states that are associated with

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[9]For a discussion of endogenous and exogenous variables see, K. C. Kogiku, An Introduction to Macroeconomic Models, New York: McGraw-Hill Book Co., 1968, p. 14.

[10]This statement is true only in relation to the popularized versions of the Keynesian model. Other methods such as dynamics, comparative dynamics, and disequilibrium dynamics are widely applied by mathematical economists to the Keynesian model. See, for example: Samuelson, pp. 278-283; R. G. D. Allen, Macro-economic Theory: A Mathematical Treatment, New York: St. Martin's Press, 1968, pp. 113-134.

different sets of values of parameters and exogenous variables."[11]

The above discussion is not meant to give an exhaustive account of the nature and method of the Keynesian analysis. It is rather intended to give an overview of this system and its methods which would provide a background for a comparison between it and Leontief's scheme. For this purpose it is convenient for later discussions to go somewhat beyond the scope of the above formulation and outline the so-called "complete Keynesian model."[12]

B. The Complete Keynesian Model

In the complete Keynesian model, the rate of interest and the level of income are simultaneously determined by the IS and LM (Hicks-Hansen[13]) schedules of the product and money markets.[14]

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[11] Alpha Chiang, Fundamental Methods of Mathematical Economics, New York: McGraw-Hill Book Co., 1967, p. 132.

[12] This terminology is due to Allen, Macroeconomic Theory . . . , p. 126.

[13] Alvin Hansen, A Guide to Keynes, New York: McGraw-Hill Book Co., 1953.

[14] For a rigorous development of the IS and LM curves see Allen, pp. 116-126; for a more elementary treatment see Kogiku, pp. 101-105. Kogiku introduces the use of arrow diagrams and "structural matrices" to study the properties of systems of equations; these tools considerably facilitate his exposition of several macroeconomic systems (including Keynes's). The use of these schemes seems to be very promising as pedagogical tools.

For the construction of the complete system, the price level is to be introduced as an endogenous variable. It is, therefore, necessary to distinguish between the "real" and the "monetary" variables. Small letters will be used to indicate the real and capital letters for money variables.

Consider the following set of equations:

(5.18) $$i(r) = s(y)\ ,\ i'(r) < 0\ ,\quad s'(y) > 0$$

(5.19) $$M = L_1(Y) + L_2(r, P)\ ,\quad M \text{ given}\ ,\ L'_1(Y) > 0\ ,$$

$$\frac{\partial L_2}{\partial r} < 0\ ,\ \frac{\partial L_2}{\partial p} > 0$$

(5.20) $$Y = Py$$

where y and r are the real variables denoting income and the rate of interest, respectively; and Y and P denote money income and the price level, respectively.

Equation (5.18) is the equilibrium condition in the product market, requiring that the forthcoming volume of saving $s(y)$ must be equal to the ex ante investment $i(r)$. The conditions $i'(r) < 0$ and $s'(y) > 0$ indicate that investment increases as the rate of interest falls and that saving increases as the level of income increases.

Equation (5.19) shows that the given supply of money M satisfies two types of demand for money: $L_1(Y)$ is that portion of the demand for money that depends on the level of income; for example, the transaction demand. $L_2(r, P)$ denotes the speculative demand for money which depends on the rate of interest and the price level. The condition $L'_1(Y) > 0$ says that the transaction demand for money increases as the level of income increases. $\frac{\partial L_2}{\partial r} < 0$ and $\frac{\partial L_2}{dr} > 0$ indicate that the speculative demand for money decreases as the rate of interest increases and that it increases as the price level rises.

The identity (5.20) defines the money income as the product of the real income and the price level.

By substituting from (5.20) into (5.19), the following set of two equations can be written:

$$(5.18) \qquad i(r) = s(y)$$

$$(5.21) \qquad M = L_1(Py) + L_2(r, P)$$

There are three unknowns and two equations in this system. Two of the unknowns can be expressed in terms of the third. Let r and y be expressed in terms of P:

$$(5.22) \qquad \begin{aligned} r &= r(P) \\ y &= y(P) \end{aligned}$$

Next consider:

$$(5.23) \qquad y = y(n)\ ,\ y'(n) > 0\ ,\ y''(n) < 0$$

$$(5.24) \qquad w = y'(n)$$

$$(5.25) \qquad W = W_0 + W(n),\quad W'(n) = 0\ (0 < n \leq \bar{n})$$
$$W'(n) > 0\ (n > \bar{n})$$

$$(5.26) \qquad W = Pw$$

where the new variables n, w, and W stand for labor, real wages, and money wages, respectively.

Equation (5.23) is the Keynesian production function which relates the level of output to the level of input of labor as the sole factor of production.[15] The conditions $y'(n) > 0$ and $y''(n) < 0$ express the phenomenon of diminishing returns.

Equation (5.24) is the schedule of demand for labor, indicating that the entrepreneurs employ labor up to the point where the real wages are equal to the marginal product of labor.[16]

Equation (5.25) denotes the supply of labor offered with infinite elasticity up to full employment level $(\bar{n})$ and with less than

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[15] Since the Keynesian analysis is concerned with the short run and in the short run the quantities of nonlabor factors of production may be assumed to remain fixed, labor is the only determinant of the level of output in the short run.

[16] In microeconomics the determination of the level of employment of labor is formulated in terms of value rather than physical quantities. It is said that the firm employs labor up to the level where the marginal revenue product of labor is equal to money wages, at given prices.

infinite elasticity once the full employment is reached. That is, the money wages are W_0 up to full employment and begin to increase beyond this level if the demand pressure persists in the labor market.

The identity (5.26) defines money wages as the product of the real wages and the price level.

By substitution from (5.26) into (5.25), the following system of equations can be written:

$$y = y(n) \tag{5.23}$$

$$w = y'(n) \tag{5.24}$$

$$Pw = W_0 + w(n) \tag{5.27}$$

which consists of three equations in four unknowns y, n, w, and P. Let y, n, and w be expressed in terms of P:

$$\begin{aligned} y &= y(P) \\ n &= n(P) \\ w &= w(P) \end{aligned} \tag{5.28}$$

Now compare the two systems of equations, (5.18) - (5.20) and (5.23) - (5.26), each giving a "half" of a complete Keynesian model. A link is provided between the two halves by the pair of variables y and P. If a price level P can be found that would make the value of y the same from each half, then the complete system is determinate and consistent.

Two points should be noted. The first is that there are enough equations to determine the variables; the complete model consisting of the seven equations (5.18) - (5.20) and (5.23) - (5.26) have seven endogenous variables:

$$y, \ n, \ r, \ w, \ W, \ Y, \ \text{and} \ P \ ;$$

the model is determinate. However, the existence and uniqueness of the solution is yet to be established. The second point is that the set of equations does not partition in any way, that there is no block of variables that can be found separately from the others. The variables are simultaneously determined by the whole of the system of equations.

The above discussion fundamentally repeats Allen's schematization of "the complete Keynesian model."[17] The study of the model will not be pursued any further here, because it is only the basic model itself which is of interest to the forthcoming discussions.

2. The Basic Leontief System

Recall from Chapter IV that the total output of a sector is identically equal to the sum of the intermediate and final demand for the product of that sector.[18] That is:

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[17] Allen, Macroeconomic Theory . . ., pp. 126-127.

[18] See Chapter IV, section 2.B, p. 14.

$$x_i = \sum_{j=1}^{n} x_{ij} + D_i \qquad (i = 1, 2, \ldots, n) \tag{5.29}$$

where x_i is the total output of sector i, x_{ij} is that portion of the output of sector i which is used as input by sector j, and D_i is the final demand for the product of sector i.[19]

It will be convenient to find numbers indicating the input requirements for the production of one unit output. These are called <u>coefficients of production.</u>[20] They are obtained by dividing the various inputs of each sector by the gross output of that sector. Thus, if a_{ij} is the production coefficient indicating the amount of product i needed to produce one unit of product j, then

$$a_{ij} = \frac{x_{ij}}{x_j} \qquad (i, j = 1, 2, \ldots, n) \tag{5.30}$$

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[19] Note that the notation adopted here is not identical with that of Chapter IV. For the purpose of theoretical analysis, the present discussion abstracts from the distinctions among the various final demand categories of Chapter IV. The complexities related to the treatment of imports are also ignored here.

[20] This terminology is due to Walras. Leontief adopted it also. Other terms such as "technical input-output coefficients" or simply "technical coefficients" are also common in the literature. See, Wassiley Leontief, <u>The Structure of American Economy, 1929-1939</u>, New York: Oxford University Press, 1960, p. 37; and Shiou-Shuang Yan, <u>Introduction to Input-Output Economics</u>, New York: Holt, Rinehart and Winston, 1969, p. 17.

It follows that

(5.31) $$x_{ij} = a_{ij} x_j \qquad (i, j = 1, 2, \ldots, n)$$

Substituting for x_{ij} from (5.31) in (5.29) gives

(5.32) $$x_i = \sum_{j=1}^{n} a_{ij} x_j + D_i \quad (i = 1, 2, \ldots, n)$$

In matrix notation:

(5.33) $$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} + \begin{bmatrix} D_1 \\ D_2 \\ \vdots \\ D_n \end{bmatrix}$$

which can be written as

(5.34) $$X = AX + D$$

where X is the total gross output vector, A is the nxn matrix of production coefficients, and D is the vector of final demand. From (5.34) one can write

$$D = X - AX$$

or

$$D = IX - AX$$

or

(5.35) $$D = (I - A)X$$

Equation (5.35) expresses the rule of transformation of gross outputs to final demand quantities. It gives the values of the final demand products that an economy with production coefficients A and gross output vector X can produce.

If the inverse matrix $(I - A)^{-1}$ exists,[21] it is possible to translate a "program"[22] of final demand into a "program" of gross outputs:

$$X = (I - A)^{-1} D \tag{5.36}$$

This transformation enables one to calculate the quantities of gross output by each sector which would be required in order to produce the given set of quantities of final demand.

The significance of this type of information cannot be overestimated. Aside from its importance for centrally-planned economies and the developing economies that depend on some degree of planning, it is of vital value to a predominantly market economy during periods

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[21] A necessary and sufficient condition for existence of the inverse matrix $(I - A)^{-1}$ is that the matrix $(I - A)$ be nonsingular, that is, the determinant $I - A$ be nonzero. This amounts to saying that the n equations in (5.32) be independent; that is, none of them be obtainable by a linear combination of others. See, G. Hadley, Linear Algebra, Reading, Massachusetts: Addison-Wesley Publishing Co., 1961, pp. 166-173. For an excellent, concise treatment see, R. Dorfman, P. A. Samuelson, and Robert M. Solow, Linear Programming and Economic Analysis, New York: McGraw-Hill Book Co., Inc., 1958, pp. 489-501.

[22] A given vector of final demand $[D_1^0, D_2^0, \ldots, D_n^0]$ may be called a program or a product mix. See, Oscar Lange,

of adjustment, say, from a peace-time to a war-time economy and vice versa. Since during such periods radical changes occur in the composition of the final demand as the proportion of war-related goods desired relative to civilian goods increases, it is important to know how each sector's total output must be readjusted in response to the new composition and level of final demand. This kind of information provides, among other things, a basis for appropriate capacity-readjustment plans in the various sectors of the economy, a measure necessary if the problem of bottlenecks is to be attacked rationally.

This completes the discussion of the simplest version of Leontief's input-output model.[23] However, several points should be mentioned before leaving the subject.

First, the quantities x_i, x_{ij}, D_i, and a_{ij} can, theoretically, be calculated in terms of physical units. But actual input-output tables are constructed exclusively in terms of money values. This is because the data in physical units are difficult to obtain. As each

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Political Economy, Vol. I: General Problems, trans. A. H. Walker, New York: The Macmillan Company, 1963, p. 209.

[23] For the most complete version see, Leontief, pp. 33-65. This complete version allows for shifts in productivity in the various sectors. It also is formulated in such a way that the model can be translated from a static setting with no accumulation in the various sectors to a dynamic one with saving and investment activities by these sectors. The model presented enough is most convenient for the study of the aggregation of sectors in later chapters.

industry usually produces many kinds of goods rather than just one kind of goods, it is difficult to consolidate various kinds of goods into an aggregate output figure by using physical units.

Second, x_i refers to the gross output of sector i. Since x_{ii} measures the portion of the output used by sector i itself, $x_i - x_{ii}$ gives the value of its net output. Estimating the net output is easier than estimating the gross output, because to obtain the latter one needs not only the intersectoral flows $x_{ij} (i \neq j)$ but also the intra-sectoral flows x_{ii}, quantities which are not readily available since many producing units do not maintain complete records of shipments among the various departments within the firm (or establishment).

Net output represents the output which can be sold to other sectors or consumers to earn revenue. When net output is positive:

$$x_i - x_{ii} > 0$$

See (5.31) $$x_i - a_{ii} x_i > 0$$

$$x_i (1 - a_{ii}) > 0$$

$$1- \ - a_{ii} > 0$$

(5.37) $$a_{ii} < 1$$

Therefore, a sector can produce some net output only if a_{ii} is less than one.[24] When a_{ii} is equal to one, all output of the sector is

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[24] It should be pointed out that the production of net output itself does not assure that some particular list of final goods is also

consumed in the production process and none is left for sale. When a_{ii} is greater than one, more are consumed than produced in the production process so that some outside stock of commodity is needed to produce nothing salable.

The actual input-output tables are constructed on a net or gross basis depending on the availability of data and cost considerations. For the theoretical discussion in the present work, both versions will be used depending on the needs at hand.

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producible. The condition $a_{ii} < 1$ follows from $x_i - x_{ii} > 0$, x_{ii} being the direct inputs of the sector. But the sector needs its own products as inputs not only directly but also indirectly through its inputs of other products. It is, therefore, possible that all the net output produced may be used up indirectly to produce that commodity. If this is the case, nothing will be left over for consumption. Thus, the ability of a sector to produce final goods depends on whether its gross output exceeds the direct and indirect input requirement of that goods itself. That is, to produce one unit of a commodity, the direct and indirect input requirement of that good itself must not exceed one unit. This is known as the Hawkins-Simon condition.

Dorfman, Samuelson, and Solow express this concept as follows: ". . . If we add up the direct and indirect inputs of coal that go into a ton of output (the coal to make coal, the coal to make coal to make coal, the coal to make steel to make coal, the coal to make steel to make coal to make coal, the coal to make steel to make steel to make coal, etc., ad infinitum), . . . all this will be less than one ton." See, Dorfman, Samuelson, and Solow, p. 215.

The Hawkins-Simon condition may be stated mathematically as follows:

$$1 - a_{ii} > 0 \quad (i = 1, \ldots, n)$$

$$\begin{vmatrix} 1 - a_{11} & -a_{12} & \cdots & -a_{1n} \\ -a_{21} & 1 - a_{22} & \cdots & -a_{2n} \\ \vdots & \vdots & & \vdots \\ -a_{n1} & -a_{n2} & \cdots & 1 - a_{nn} \end{vmatrix} > 0$$

Third, the above model is called an open Leontief model because there are some quantities of output which are determined outside the model. Specifically, the set of final-demand values $D_1, D_2, \ldots, D_n$ are fixed exogenously; the model itself determines the values of the endogenous variables $x_1, x_2, \ldots, x_n$ on the basis of the given final demand values and the production coefficients (or the parameters of the model).

The model can be "closed" by defining production coefficients for the final demand entries and treat the final demand values as inputs for the household sector whose output is labor.[25] Although Leontief's original formulation was developed as a closed model, further experience has shown that the open model is superior in flexibility and applicability.[26]

Fourth, the above model is a static one based on the assumption that the total outlays of each sector is equal to its total receipts.

See, D. Hawkins and H. A. Simon, "Note: Some Conditions of Macroeconomic Stability," Econometrica, July-October, 1949, pp. 245-248. For a graphical and analytical discussion of this for the case of a two-sector economy, see, Dorfman, Samuelson, and Solow, pp. 212-215.

[25] A detailed and specific development of the closed model is not undertaken because it does not serve the purpose of this study. The problem of aggregation is the same with regard to both models. For a simple treatment of the closed model see, Yan, pp. 39-41.

[26] Cf. the new chapters of the 1951 edition of Leontief, The Structure of American Economy, 1929-1939, with the old.

Under actual dynamic conditions, a part of outlays are expenditure on capital equipment not current production. To finance this capital expansion, the producing units may draw on accumulated savings of the past or draw on current revenues.[27] The problem of aggregation will be studied in relation to the static model alone. It appears that the nature of the problem would vary significantly in going from the static to the dynamic model. Therefore, the fact that the aggregation problem is studied exclusively in relation to the static model in this work is only due to the necessity of limiting the scope of the study. An investigation of the problem in relation to the dynamic model can by itself provide subject for a sizable research project.

Fifth, the model presented above is based on a number of assumptions which should be made explicit. Since some of these are directly related to the problem of aggregation of industries, their consideration is best postponed to the next chapter where the aggregation problem is treated in detail. Only the assumptions related to the production coefficients will be discussed here. Since production coefficients constitute the very core of Leontief's models, it is necessary to examine them in detail.

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[27] For an excellent discussion of dynamic input-output models, see, Dorfman, Samuelson, and Solow, Chapters XI and XII. For a more elementary treatment see, Yan, pp. 124-126; and Hollis B. Chenery and Paul G. Clark, Interindustry Economics, New York: John Wiley and Sons, Inc., 1967, pp. 71-79.

A. Production Coefficients and Production Function

Recall from Chapter IV that inputs of industry j consist of two types: the produced inputs $[x_{1j}, x_{2j}, \ldots, x_{nj}]$ and the primary inputs which will be denoted by x_{0j}. Then the production function for the j-th sector can be written in general form as:

$$(5.38) \qquad x_j = x_j(x_{0j}, x_{1j}, x_{2j}, \ldots, x_{nj}) \quad (j = 1, 2, \ldots, n)$$

where x_j denotes the gross output of sector j as well as a functional notation for the production function of that sector. In this general form, this production function differs from the ones usually assumed in microeconomics in that it has inputs of not only primary resources but also currently produced commodities. In contrast with this, the traditional production function may be written as:

$$(5.39) \qquad Q = Q(K, L, N)$$

where K, L, N denote capital, labor, and land; Q denotes output as well as the functional notation for the production function. Thus, the traditional production function is formulated in terms of the primary inputs alone, leaving currently-produced inputs out of the picture. The more recent literature of mathematical economics, does not conform to the traditional formulation.[28]

Further, the set of production functions in (5. 38) consist of n separate production functions, one for each sector of the economy.

Leontief makes two specific assumptions with regard to the production function in (5. 38):

(a) constant returns to scale;

(b) fixed coefficients of production.

He supposes that it takes a certain minimal input to each commodity (possibly zero) per unit of output of each commodity. "The word 'minimal' is of some importance; if it takes two tons of ore to yield one ton of iron, no doubt the same iron could be produced from even more ore, but as long as iron ore has value, nobody will be silly enough to use more than the absolutely required two tons."[29]

This special Leontief function can be written in the usual form (5. 38). Let a_{ij} be the required minimal input of i-th per unit output of j-th sector.

Then,

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[28] Cf. Henderson, J. M. and Quandt, R. E., Microeconomic Theory: A Mathematical Approach, New York: McGraw-Hill, 1958.

[29] Dorfman, Samuelson, and Solow, p. 209.

$$x_j = \min\left(\frac{x_{0j}}{a_{0j}}, \frac{x_{1j}}{a_{1j}}, \frac{x_{2j}}{a_{2j}}, \ldots, \frac{x_{nj}}{a_{nj}}\right) \tag{5.40}$$

$$(j = 1, 2, \ldots, n)$$

Now note that if every input is increased λ-fold the output will be λ times greater also; that is, the function (5.40) is subject to constant returns to scale:

$$\min\left(\frac{\lambda x_{0j}}{a_{0j}}, \frac{\lambda x_{1j}}{a_{1j}}, \frac{\lambda x_{2j}}{a_{2j}}, \ldots, \frac{\lambda x_{nj}}{a_{nj}}\right)$$

$$= \lambda \min\left(\frac{x_{0j}}{a_{0j}}, \frac{x_{1j}}{a_{1j}}, \frac{x_{2j}}{a_{2j}}, \ldots, \frac{x_{nj}}{a_{nj}}\right)$$

$$= \lambda x_j \tag{5.41}$$

A function with this property is said to be homogeneous of degree one.

If a_{ij} is zero (a commodity not needed at all in a certain industry), the corresponding term from the right-hand side of (5.40) can be omitted. Alternatively, $\frac{x_{ij}}{a_{ij}}$ can be regarded as infinity, in which case it will certainly never be the limiting smallest number in (5.40).

Another way of writing (5.40) is to note that since x_j equals the smallest of $\frac{x_{0j}}{a_{0j}}, \frac{x_{1j}}{a_{1j}}, \frac{x_{2j}}{a_{2j}}, \ldots, \frac{x_{nj}}{a_{nj}}$, it must be less than or equal to all $(n + 1)$ of the ratios:

$$x_j \leq \frac{x_{ij}}{a_{ij}} \qquad (i = 0, 1, 2, \ldots, n) \tag{5.42}$$

or, written out in full,

$$
\begin{array}{llllll}
x_{01} \geq a_{-1}x_1, & x_{11} \geq a_{11}x_1, & x_{21} \geq a_{21}x_1, & \ldots & , x_{n1} \geq a_{n1}x_1 \\
x_{02} \geq a_{02}x_2, & x_{12} \geq x_{12}x_2, & x_{22} \geq a_{22}x_2, & \ldots & , x_{n2} \geq a_{n2}x_2 \\
\vdots & \vdots & \vdots & & \vdots \\
x_{0n} \geq a_{0n}x_n, & x_{1n} \geq a_{1n}x_n, & x_{2n} \geq a_{2n}x_n, & \ldots & , x_{nn} \geq a_{nn}x_n
\end{array}
\tag{5.43}
$$

with equality holding at least once in each row (in fact, with equality holding everywhere if none of the commodities concerned are free goods).[30]

Matrix A in (5.34) is an nxn matrix whose elements are a_{ij} (i, j = 1, 2, . . . , n) as defined in (5.43) above. This matrix is the production function of the economy consisting of n separate production functions as each of its columns describes the production function of the corresponding industry. It exhaustively depicts the technology interrelationships within the economic system.

In order to compare the Leontief with the traditional production function, the general form (5.39) is not of interest; it must be given a concrete content by means of either imposing some restrictions on it--such as, for example, requiring its first and second derivatives to be positive and negative, respectively, indicating diminishing returns--or

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[30] *Ibid.*, pp. 209-210.

by specifying the function by means of a formula. This latter alternative will be chosen here.

The specific production function used most often for theoretical and empirical work both in micro- and macroeconomics is the Cobb-Douglas production function. There are other production functions, such as the C.E.S.[31] function, which are of considerable theoretical interest. But the relative simplicity as well as the popularity of the Cobb-Douglas function as compared with the C.E.S. or other specific functions lead one to prefer it to the other forms.

3. Cobb-Douglas Production Function

The general form of the Cobb-Douglas function is $Q = AK^{\alpha}L^{\beta}$ where A is a constant coefficient and α and β are positive parameters.[32] K and L are inputs of capital and labor, respectively; and Q denotes output. The constant A is a parameter of the

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[31] C.E.S. stands for "constant elasticity of substitution." This function includes the Cobb-Douglas production function as a special case. See, K. J. Arrow, H. B. Chenery, B. S. Minhas, and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency," Review of Economics and Statistics (August, 1961), pp. 225-250; for a more elementary treatment see, Chiang, pp. 382-384, or Hans Brems, Quantitative Economic Theory: A Synthetic Approach, New York: John Wiley and Sons, Inc., 1968, pp. 69-70.

[32] M. Bronfenbrenner and P. H. Douglas, "Cross Section Studies in the Cobb-Douglas Function," Journal of Political Economy, December, 1939.

overall productivity, and it can be absorbed[33] into the units chosen for measuring output Q. Therefore, with a proper choice of units, the Cobb-Douglas function can be written as:

$$(5.44) \qquad F(K,\ L) = Q = K^{\alpha}L^{\beta} \quad (\alpha > 0,\ \beta > 0)$$

This function is homogeneous of degree $\alpha + \beta$:

$$(5.45) \qquad F(\ K,\ \ L) = {}^{\alpha+\beta} K^{\alpha} L^{\beta}$$

Hence, there are increasing returns to scale if $\alpha + \beta > 1$ and decreasing returns to scale if $\alpha + \beta < 1$. For constant returns to scale, $\alpha + \beta = 1$ or $\beta = 1 - \alpha$. Thus, the Cobb-Douglas function with constant returns to scale has only one parameter:

$$(5.46) \qquad Q = K^{\alpha}L^{1-\alpha} \quad \text{where} \quad 0 < \alpha < 1$$

The marginal products of capital and labor are:

$$(5.47) \qquad \frac{\partial Q}{\partial K} = \alpha K^{\alpha - 1} L^{1-\alpha} = \frac{\alpha K^{\alpha} L^{1-\alpha}}{K} = \frac{\alpha Q}{K}$$

$$(5.48) \qquad \frac{\partial Q}{\partial L} = (1 - \alpha) L^{-\alpha} K^{\alpha} = (1 - \alpha)\frac{L^{1-\alpha}K^{\alpha}}{L} = \frac{(1 - \alpha)Q}{L}$$

Now the ratio of the marginal products (or the "marginal rate of substitution") is:

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[33] Allen, <u>Macroeconomic Theory . . .</u> , p. 49.

(5.49)
$$\frac{\partial K}{\partial L} = \frac{\frac{\partial Q}{\partial L}}{\frac{\partial Q}{\partial K}} = \frac{\frac{(1-\alpha)Q}{L}}{\frac{\alpha Q}{K}} = \frac{1-\alpha}{\alpha} \cdot \frac{K}{L}$$

That is, the equivalent of one unit of labor in production is $\frac{1-\alpha}{\alpha} \cdot \frac{K}{L}$ units of capital. Therefore, under competitive conditions, the price of labor P_L must be $\frac{1-\alpha}{\alpha} \cdot \frac{K}{L}$ times the price of capital:[34]

(5.50)
$$P_L = \frac{1-\alpha}{\alpha} \cdot \frac{K}{L} P_K$$

It follows that:

(5.51)
$$\frac{K}{L} = \frac{\alpha}{1-\alpha} \cdot \frac{P_L}{P_K}$$

Equation (5.51) is a very important result. It indicates that the capital/labor ratio is constant as long as the relative price of the two factors remain the same, provided that the production function is of Cobb-Douglas form.[35] In particular, the optimal factor-combination ratio is independent of the level of output. Once the ratio is established by profit-maximizing entrepreneurs, it continues to be

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[34] For further discussion along this line see, Yan, pp. 26-29. Yan avoids calculus to keep the level of treatment elementary. But his arguments are essentially those presented above.

[35] Note that the assumption of constant returns to scale is not necessary for arriving at the above conclusion. For the case of $\alpha + \beta \neq 1$ the condition will be stated as

optimal as long as the parameter of the production function α and the relative price $\frac{P_L}{P_K}$ remain the same.

Therefore, the Cobb-Douglas production function presented above not only is subject to constant returns to scale, but also it displays the phenomenon of constant input ratios. That is, the ratios of various inputs to one another on the one hand and to output on the other are constant coefficients. But this is precisely the assumption of Leontief's production function! The only difference is that the constancy of the coefficients in the case of the Cobb-Douglas function is the result of the optimizing behavior of entrepreneurs under competitive conditions, whereas, in the case of Leontief's function, it is based on the assumption of technical nonsubstitutability.

The above formal analogies between Leontief's production function and a particular smooth neoclassical function--the Cobb-Douglas function--should not blur the sharp differences that exist between the Leontief and the general neoclassical function. The latter is characterized by smooth substitutability among factors and diminishing returns to each factor when all the other factors are held constant.

Leontief notes that "far reaching theoretical consequences

$$\frac{K}{L} = \frac{\alpha}{\beta} \frac{P_L}{P_K} .$$

ensue from our choice of this particular function [that is, Leontief's type]. It means no less than a formal rejection of the marginal productivity theory; in this setup all factors appear to be strictly complementary or limitational. The marginal productivity of any of them . . . equals zero: the output would not increase unless the inputs of all other factors were also increased according to their respective coefficients of production. The same restriction can be formulated in another way by saying that our production functions exclude technical substitutability of factors within the framework of any given production process. . . . "[36]

Nevertheless, as Dorfman, Samuelson, and Solow have done, within a broader framework, the analysis can be pushed much further; and many of the formal properties of one type of production function can be established for the other type as well.[37]

It is interesting to note that the empirically-oriented formulations of production function tend to be much more disaggregative than the usual theoretically oriented ones.[38]

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[36] Leontief, pp. 38-39.

[37] Dorfman, Samuelson, and Solow, pp. 375-381.

[38] Cf. Hildebrand, G. H., and Lu, Ta-Chung, Manufacturing Production Functions in the United States, 1957, New York: W. F. Humphrey Press, Inc., 1957.

4. Summary and Contrast

This chapter was devoted to the study of the theoretical foundations of national income and input-output accounting. The accounting schemes studied in the last chapter were based on the logical frameworks presented here. Indeed, the latter do not merely provide a guide to social accounting; they are the principal justification for it. Social accounting is primarily an attempt to abstract empirically certain features of the social economy which a given theory deems as essential. The two accounting systems studied in the preceding chapter and the corresponding theoretical systems studied in this chapter are related in this manner.

Another objective of the theoretical discussion in this chapter was to provide some of the apparatus needed for the analysis of the problem of aggregation to be studied in the following chapter.

Finally, a comparative study of two such important theoretical frames is justifiable in its own right. These two are the most important thought trends in recent macroeconomic theory.

A comparison of the two systems as presented above reveals certain differences and similarities which can be outlined as follows:

Both systems treat the national economy as the system under investigation. Therefore, their theoretical model is about the whole (not a portion) of the economic system. The models proposed involve systems of simultaneous equations, solutions of which yield the values of certain macroeconomic variables which are proposed to be determined by the system. In order to translate the general theoretical formulation into a specific, empirical model, it is necessary to estimate the values of the parameters. The parameters of the input-output analysis are the coefficients of production, and those of the Keynesian system are the coefficients of the variables in the model.

Both theoretical systems attempt to "explain" or determine the values of some macroeconomic variables by the model and leave others either completely out of the model or as exogenous variables--that is, quantities that are given on the basis of informations which are not present in the model itself. Whether a particular variable is treated as exogenous or endogenous depends on the scope of the particular formulation of the model at hand in either case. For example, consumption expenditures and income are treated as exogenous variables in the open Leontief system; whereas another particular formulation of the model may treat them as an endogenous variables. In sum, the general equilibrium framework with all its methodological ramifications is common to both systems. Even though the discussion in this chapter was developed strictly along static and comparative static terms, a review of the literature shows that dynamics, comparative dynamics, and disequilibrium dynamics provide channels of further development in either system.

Hence, the essential differences cannot be traced to the object of study--for both systems are concerned with the national economy as the unit of study--or to the methodological features. Instead, it is the particular assumptions made about the internal structure of the national economy that constitute the area of differences.

The Keynesian system views the national economy as a whole which can be understood by means of studying few aggregate quantities and the mode of their interdependence. An overall consumption function, investment-expenditures function, money-demand functions, labor-market functions, and finally the aggregate production function provide the basis for analyzing the behavior of the national economy as a whole. In contrast to this, the Leontief system requires a detailed setup which describes the economy in terms of its many sectors and the mode of interdependence of these sectors. The Leontief system is concerned with the structure of the economy as revealed by the network of exchanges that continually occur between the various producing units of the national economy.

Since the Keynesian system is formulated in terms of very broad aggregates to begin with, the problem of further aggregation within it is nonexistent and at best trivial. But the problem is immensely important in relation to input-output analysis. Indeed, as it will be shown in the following chapters, the very concept of "sector" directly involves an examination of the aggregation problem. It will be shown that the Leontief system has provided, for the first time, a framework for a systematic study of collection and classification of data in relation to the national economy. The importance of this contribution will be appraised in a separate chapter devoted to the survey of empiricism in economics and other sciences.

CHAPTER VI

AGGREGATION AND CLASSIFICATION

In the previous chapters the essential features of the Keynesian and Leontief theoretical systems were presented. This was done in order to provide the background information necessary for the analysis of the aggregation problem. It will be shown that the aggregation problem is trivial in relation to the Keynesian model but extremely important in relation to the Leontief system. In the Keynesian models this problem is expected to be coped with by those who attempt to specify the model statistically. Thus, in an ultimate sense the problem does not disappear; it simply changes hands. At any rate, it is necessary to make the assumptions of the input-output analysis explicit because this has a direct bearing on the aggregation problem. This is done in the first section.

Section 2 presents the nature of the aggregation problem. This is followed by a formal study of the question in section 3. Sections 4 and 5 discuss the modifications to be expected with regard to the theoretical propositions derived in section 3. These are both of a theoretical as well as empirical nature.

1. Assumptions of Input-Output Analysis

Input-output analysis conceives the economic system as consisting of a number of sectors. The basic assumptions of input-output analysis relates, therefore, to the definition of a sector, its technical and economic behavior, and the mode of its interrelationship with the other sectors in the economy. A precise statement and evaluation of these aspects of the problem is necessary if a comprehensive view of the nature of input-output analysis is desired. It turns out that the aggregation problem is of central importance to this argument. Therefore, the argument can justifiably be developed in detail.

A sector is defined as a productive unit with the following characteristics:

(1) It produces commodities which are homogeneous, homogeneity being understood as perfect substitutability in all uses. This implies that each sector produces one and only one commodity.

(2) It applies only a single technique of production. By "technique of production" is meant the relative quantities of various inputs used for the production of its output.

(3) Its inputs depend solely on the level of its output. Usually the stronger assumption of linear dependence is assumed. That is, the production function in a sector is assumed to be subject to constant returns to scale.

(4) The total effect of carrying on several types of production is the sum of the separate effects. This is known as the additivity assumption.[1]

These are the necessary theoretical criteria related to the concept of sectors in input-output analysis. Needless to say, these are very restrictive requirements. But this restrictiveness is not as much as it might appear on a first examination of the problem. The problem must be scrutinized closely.

As far as the first requirement--the assumption that each sector must produce only a single commodity--is concerned, there seems to be little difficulty expected. The economy can easily be thought of as a collection of productive units, each of which produces a single commodity. The only serious difficulty here is that it may lead to a model with several thousand sectors, one that would not be of much practical value with the existing computing technology. As far as theoretical considerations are concerned, an increase in the number of distinct sectors in the model does not affect the qualitative complexity of the model.

The second assumption, which states that each sector applies

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[1] Chenery and Clark, pp. 34-35; and Edmond Malinvaud, "aggregation Problems in Input-Output Models," The Structural Interdependence of the Economy; Proceedings of an International Conference on Input-Output Analysis, Verna, June-July, 1954, ed. Tibor Barna, New York: John Wiley and Sons, Inc., 1955, pp. 192-93.

only a single productive technique, appears to be a direct denial of the notion of factor substitution which is so commonly accepted in traditional economics. Two types of related but distinct propositions lie behind the notion of continuous factor substitution: First, it is argued that a given commodity is producible with many alternative productive techniques. Second, it is held that the "optimal" productive technique is selected by the entrepreneurs on the basis of the relative prices of inputs. Should these relative prices change, the profit-maximizing entrepreneurs will resort to a new technique with a new set of relative input quantities. Leontief argues that this mode of argument depends heavily on the use of highly aggregative concepts in the traditional economic theory:

> A large number of economic phenomena, which in economic discussion are referred to as instances of factor substitution, prove upon closer examination to be of a quite different nature. The conventional interpretation of the marginal productivity theory is very often linked with the rather broad, not to say undiscriminating use of the term 'factor of production.' The venerable trinity of 'land, labor, and capital' seems still to dominate the field of theoretical discussion. It is closely linked with the traditional approach to the system of national economy as if the latter were a single tremendously complicated production process absorbing the services of land, labor, and capital on the one side and throwing out the national product on the other. If further differentiation is introduced at all, it rarely goes beyond the conventional distinction between consumers' and producers' goods industries. Now, if we compare this simplified scheme with the more realistic picture of our economic system, which instead of one, two, or three would include dozens of separate industries, it becomes evident that the concept of technical substitution and the

> law of variable proportions--if <u>applied to aggregative industries</u> (Emphasis added, M.M.)--have in the main no other function than to conceal the nonhomogeneous character of the conventional industrial classification. If two heterogeneous subdivisions of the consumption goods industries--for example foodstuffs as contrasted with the automobile industry--are using land, labor, and capital in fixed but significantly different proportions, any change in their relative size will necessarily be accompanied by a variation in the relative amounts of land, labor, and capital absorbed by the consumption goods industry as a whole. Many an economist will interpret this phenomenon as a change in factor combination within the consumption goods industry.[2]

Further arguing along the same line, Leontief notes that frequent reference to substitutability of factors is made simply to offset a certain blurredness of the aggregative concepts used.[3]

The above argument is not meant to propose that the assumption of fixed coefficients is completely realistic. This assumption "necessarily entails the existence of some disparity between our theoretical scheme and the actual industrial setup it is intended to represent. Empirical investigation alone can reveal how significant this disparity actually is."[4]

However, some degree of factor substitution is not incompatible with the fixed coefficients assumption. Here the degree of

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[2]Leontief, <u>The Structure. . .</u>, 39.

[3]<u>Ibid.</u>, p. 40.

[4]<u>Ibid.</u>

complementarity might be so high that even a most violent variation in their relative prices could affect the relative amounts of input only slightly. As for the case of high degrees of substitutability, Leontief has this to say:

> Paradoxically as it may seem, some instances of extreme substitutability will often be more favorable to our assumption of rigid proportions than even cases of high complementariness. Take the example of two metals which from a technical point of view are equally well adapted to some particular productive use. Obviously one critical price ratio must exist at which the relative costs of using one or the other will be exactly the same. In all other uses, the relatively cheaper material will be used exclusively. The most violent price fluctuation cannot have even the slightest effect on the resulting factor combination so long as it does not swing the balance to the other side of the critical price ratio. In all the numerous cases in which every cost factor has an unlimited range of possible substitutes, the actual price variations are safely removed from such critical points, so that the assumption of constant proportions is for all practical purposes entirely justified.[5]

There is, of course, no way to prove the last statement a priori. The following observations may make it plausible: Take two inputs such as copper and silver. As conductors of electricity these are substitute goods in many instances. Suppose silver is 15 times more efficient in this capacity than copper. Then as far as this particular use of the two metals is concerned, the critical price ratio is $\frac{p_s}{p_c} = 15$.

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[5] Ibid., pp. 40-41.

$\left(\frac{p_s}{p_c}\right)^*$ But there is no necessity for the actual price ratio, call it to be equal or even close to this critical ratio. This is so because the actual price ratio is determined by the supply and demand conditions in the market, whereas the critical price ratio reflects the technical use of the two metals in one particular capacity, namely, conduction of electricity. In general, material inputs are used in many different capacities, so that the part of demand for such inputs related to one particular use can be expected to be not so significant as playing a determining role in the market..

For the actual price ratio to be close to the critical ratio relative to a particular use, the following two conditions must be presented:

(a) Relative lack of other uses for the two products. In case of copper and silver this condition is not satisfied because obviously there are many capacities other than electricity conduction in which these metals are used. In general, the higher the particular demand as a proportion of the total demand for each of the two products, the more the influence of the particular use of these products on the actual relative price. In such cases the actual relative price is "pulled" close to the critical ratio.

(b) The less elastic the supply functions of each of the two products, the greater the tendency of the actual ratio to be close to the critical price ratio. This tendency may be negated by demand considerations as outlined in (a) above. This point is obvious because the only significant dependence between the actual and critical ratio is likely to be through the demand side and for demand to be important as a determinant of price, it is necessary to have a relatively inelastic supply schedule.

Note that neither (a) nor (b) is a sufficient condition by itself. For example if the supply functions are perfectly elastic, then the actual ratio is completely independent of the critical price ratio. On the other hand, if the supply schedules are perfectly inelastic but the respective demands for the two products constitute only insignificant proportions of the total demands, then again the two price ratios shall not be expected to be close except for the chance element.

Further note that both conditions above must be simultaneously present for each of the two products. Hence there are four necessary (and in general independent) conditions that must be present in order for the actual and critical price ratios to be close out of necessity (rather than purely out of chance). Not many commodities can be expected to satisfy these conditions, though the truth of this proposition must be established by empirical studies.

The foregoing discussion shows that when the highly aggregative concepts are abandoned in favor of more differentiated ones the assumption of a single productive technique ceases to be as unrealistic as it appeared at first. Leontief's fixed coefficients assumption is, therefore, an approximation to reality.

However, Samuelson has shown that in the case of a single primary factor (labor), it is permissible to ignore substitution among inputs. This is the so-called "substitution theorem."[6]

The third assumption which holds that the production function in each sector is subject to constant returns to scale has already been studied in some detail in section 2 of Chapter V. It may be noted that this linearity assumption is resorted to purely due to theoretical and practical convenience. Further development in data availability and computing methods may make it possible to set up the model with non-linearity assumptions such as increasing returns to scale.

Finally, the fourth assumption rules out external economies and diseconomies. More formally stated, the additivity assumption can be expressed as

$$A + B = (A + B) \tag{6.1}$$

where

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[6]See Dorfman, Samuelson, and Solow, pp. 224-27; for a more patiently exposition see Chenery and Clark, pp. 107-108.

$$(6.2) \qquad A = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{bmatrix}, \quad B = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix}, \text{and } (A+B) = \begin{bmatrix} a_1 + b_1 \\ a_2 + b_2 \\ \vdots \\ a_n + b_n \end{bmatrix}$$

with a_i, b_i and $a_i + b_i$ being the i-th input (output) of the given industries. In specific terms (6.1) states that two industries a and b have the same pattern of interrelationship with the rest of the economy whether they are separate industries or are integrated into one. In other words, there are no significant gains or losses to the economy when two (or more) industries are integrated into one.

It may appear that this assumption is not realistic in view of the fact that there has been a definite upward trend in vertical integration among many American firms in recent years. One could argue that this trend is an indication of the existence of significant external economies which have induced the entrepreneurs to try to capture--or, so to speak, internalize--the external effects. Put otherwise, it may be asked if vertical integration is not of advantage why are there such strong tendencies towards it? It should be realized, however, that the phenomenon of vertical integration is a very complex one and that many competing hypotheses may be offered in attempting to explain it. For example, the desire on the part of the firms to diversify their "real" investment portfolio, and sociological factors such as prestige and related factors may be more important than external economies as stimulants toward integration.[7] Thus, it is very easy to overemphasize the extent of externalities in reference to the integration of industries. The question can only be resolved on the basis of empirical evidence.

To be sure one can think of situations in which externalities are present more or less significantly. Take, for instance, the classical example of producing money and apples. If apple trees are within the activity range of the bees, then the pollinating work of the bees leads to a better apple crop and the existence of apple blossoms as a source of food leads to better results in the production of honey. Here, then, the integration of the two types of productive activities has an outcome which is more than the algebraic sum of the separate effects of the two activities. This negates equation (6.1).

In general whenever waste products of one process can serve as an inputs in another process, then externalities are definitely present. Perhaps in chemical and related industries there are many instances of such externalities. The point shall not be pursued further here as it would necessitate a lengthy digression.

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[7] Robert N. Grosse, "The Structure of Capital," in Leontief Studies in . . . , p. 186.

One final note must be made, however, in relation to the number of sectors in an input-output model as related to the phenomenon of external economies. It may be that as the number of sectors increases the extent of externalities increases also. This can be explained in the following way. Suppose the economy is conceived of as one production sector only. Then there are no externalities since all effects are internal to the system as a whole. Next suppose the economy is conceived of as consisting of two different sectors, namely, industry and agriculture. Now the phenomenon of externality appears, at least in principle. For example roads and other transportation facilities built for the shipment of industrial inputs or products may have favorable effects on the agricultural sector in one way or another. The argument can obviously be generalized.

The foregoing discussion has been limited to the fundamental assumptions of input-output analysis with an eye on the problem of aggregation. A more exhaustive study of these assumptions may be found in Balderston's article[8] where he contrasts the Leontief model with a number of other general equilibrium schemes. These include Walras's, von Neumann's, and the Air Force model.

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[8] J. Balderston, "Models of General Equilibrium," Economic Activity Analysis, ed. Oscar Morgenstern, New York: John Wiley and Sons, Inc., 1954, pp. 30-33.

The above discussion indicates that the objective of the assumptions of the input-output model is to divide the economy into a set of mutually exhaustive parts with a specified mode of interrelationships among these parts. Is there a unique way of doing this? What are the consequences of changing a given pattern of subdivision of the economy? These relate to the nature of the question of aggregation.

2. The Nature of the Aggregation Problem

Investigation of the problem of aggregation in general is not of interest to this study.[9] Only a particular type of aggregation--that which is related to the question of industrial classification--is studied here. Nevertheless, some brief notes on the problem in its more general setting help to draw sharper lines in identifying the problem. Allen presents the issue most completely:

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[9]The most systematic study of the aggregation problem published to date is Henry Theil, Linear Aggregation of Economic Relations, Amsterdam: North-Holland Publishing Co., 1954. An introduction to the subject is provided in R. G. D. Allen, Mathematical Economics, New York: Macmillan and Co., Ltd., 1963, Chap. XX. These works are interested in deriving the general principles of aggregation "from micro-relations to appropriate macro-relations." [See Allen, p. 694.] This approach to the aggregation problem is much more general than that related to the input-output models. The former does not specify what the specific nature of the "micro" and "macro-relations" referred to is. The latter does precisely this. To that extent the aggregation problem assume a more concrete formulation within the framework of the input-output models, providing directly applicable criteria of aggregation in empirical works.

Economic models must be related to empirical data if they are to be of use either for explanatory or for predictive purposes. In the present state of computational procedures, they must involve relatively few aggregates like national income, consumption and investment, or inputs or outputs of broad groups of materials and products. This is certainly so for models of the whole economy, as in Hicks' trade-cycle theory . . . or Leontief's input-output model. . . . In most cases, a model must be confined to a few macro-relations between a few micro-variables.

Macro-economic models can be set up in their own right . . . on the assumption that, at least approximately, aggregate variables are directly and simply related. However, this can not be satisfactory to an economist, conscious that relations between aggregates are the resultant of many decisions by consumers and firms. It is natural to wish to go behind the macro-relations, to see how individual decisions lead to stable relations in the aggregate--if indeed they do so at all.

. . . The economic theory of any model runs in micro-terms, based on decisions taken, e.g., by individuals, consumers or firms; the macro-relations are derived constructions. There must be an explicit translation, through aggregation, from micro-relations to appropriate macro-relations. . . . The method of aggregation is vital, both in its economic aspect and in its statistical connotation in relation to available data.

A host of questions emerges. What kind of aggregation is needed? . . . Once aggregate variables are written, how are they to be related? . . . What is the relation of the (statistical) coefficient of a macro-relation to the corresponding (economic) coefficients in the basic micro-relations? The market price-elasticity of demand for tea, for example, may be thought of as an average of diverse individual price elasticities. Is this appropriate and, if so, what kind of average is the aggregate coefficient? Such qudstions are clearly fundamental in economic model building. . . . [10]

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[10] Allen, <u>Mathematical . . .</u> , pp. 694-695.

Thus the prevailing methodology in economic theory (artificially) dichotomizes the conceptualizing process of cognition of economic phenomena into micro- and macro-perception. Some of the consequences of this way of perceiving economic processes were investigated in Chapter III. It may be repeated here that the micro-macro dichotomy is another manifestation of what was termed the "fundamental dichotomy"--separation of empirical and theoretical economies into two different compartments--in Chapter III. The task of aggregation is to negate the micro-macro dichotomy. This is the type of aggregation that has interested some theorists as well as empiricists in recent years. However, it is the aggregation within a Leontief model that is of interest in this chapter.

Within the input-output framework the aggregation problem is both concrete and well-defined. Here the analysis seeks to discover methods of aggregating various sectors "on condition that the particular laws of economic theory are not changed as a result."[11] This is a "logically correct condition and it is obvious since it is difficult to imagine the laws of economic science being dependent on the manner in which the output of various sectors is combined."[12]

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[11]Oscar Lange, Introduction to Econometrics, New York: The Macmillan Company, 1963, p. 250.

[12]*Ibid.*

Lange observes that this principal of "invariance of economic laws" with respect to the aggregation procedure is analogous to the question of selecting the system of coordinates in the study of physical phenomena. "For we know, for instance, that the system of coordinates may be changed on condition that the laws of physics are not changed in the new system of coordinates. This is the fundamental idea of the theory of relativity."[13]

More specifically the theoretical problem can be formulated in the following terms: Given a basic statistical setup describing some particular economic system as composed of n separate industrial accounts; by consolidation of two of these n industries this setup is transformed into another which consists of only n-1 industries. What is the difference between the analogous price and quantity derivatives as computed on the basis of the complete and the consolidated setup?[14]

For a complete presentation of the problem it is worth it to quote Leontief in full:

> . . . Let us visualize a very simple (!) economic systems consisting of households and of one hundred closely delineated and thus sharply distinguishable industries. Let us furthermore assume that the internal structure of each one of these one hundred individual industries can be accurately described in terms of a set of (at most) one hundred constant technical input

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[13] Ibid.

[14] Leontief, The Structure . . . , p. 126.

> coefficients and finally that the numerical magnitudes of all these coefficients are actually known and available in the form of a 100 x 100 table . . . . Let us proceed now to determine the effect of an increased final demand for the products of, say, the automobile industry upon the total output of the paper industry. Following the previously described procedure, we form a system of one hundred linear equations and solve it for the total output of the paper industry in terms of the final demand for automobiles. . . . The numerical results of this computation will depend not only upon the technical structure of the two industries immediately involved but also upon the magnitudes of the input coefficients of each one of the other ninety-eight industries.
>
> Under the given assumptions the answer thus obtained will obviously be entirely correct. That is, if after having finished theoretical computations we had performed the difficult but still possible controlled experiment of increasing the final demand for automobiles and observed what happens to the paper output, the latter will have changed exactly by the amount predicted by the previous theoretical computation.[15]

If the computing devices were not capable of solving the 100 x 100 system of equations,[16] it would be necessary to reduce the number of individual industries by a process of reclassification and

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[15] Ibid., pp. 208-209.

[16] In relation to this point Leontief writes that "even if the construction of an exhaustive table describing all the transactions between the independent economic units within the national economy were possible, the very size of such a table would constitute a serious impediment to any profitable use of information contained in it. Obviously, considerable simplification of the original scheme is essential. The first step towards such a simplification is the grouping of accounts. . . ." Ibid., p. 14.

consolidation. Suppose the automobile and paper industries are kept unchanged as control industries and the remaining ninety-eight of the original industries are combined in forty-eight groups some of which would now contain at least two or more of the original industries.

The new 50 x 50 system of equations can be solved to show the effect of increased final demand for automobiles upon the paper output.

This new result can be compared with the true answer obtained on the basis of undistorted data (and also checked by subsequent controlled experiment). Most probably the new answer will differ by a larger or smaller amount from the correct one.

> There are many alternative ways of aggregating the ninety-eight original industries under some forty-eight broader headings. Each reclassification will lead to a different system of fifty simultaneous equations and most likely also to a different solution. By comparing these alternative short-cut answers with the known correct solution of our problem, on the one hand, and with each other, on the other, it is possible to measure the comparative 'goodness,' i.e., operational efficiency, of alternative aggregative classifications of the ninety-eight basic industries. . . .[17]

In the case of the hypothetical 100 x 100 matrix of coefficients one can talk about a "true" solution but such a matrix for the actual economic system is not available, if it exists at all. Nevertheless the

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[17] *Ibid.*, pp. 209-210.

above idealized model does show that if the classification scheme applied to the actual economy closely conforms with the theoretical criteria, then one can talk about a "true" solution even if the existing computing facilities are not capable of obtaining such a solution.

The fact that the size of the matrix of coefficients is limited by existing computing facilities implies that in the empirical implementation of the input-output model some degree of aggregation is unavoidable. As Leontief puts it: ". . . The practical choice is not between aggregation and non-aggregation but rather between a higher and lower degree of aggregation."[18]

In a previous chapter an aggregative scheme was presented which embodied both the Keynesian and Leontief models as special cases. Here the question of aggregation is treated from a different angle. It is the question of invariance of the solution to the input-output model in industries that is of interest here.

Such consolidation must be achieved on theoretical considerations because the ideal matrix of coefficients, and therefore the "true" solution, is not available. There is no empirical norm against which the solution to an aggregated system can be appraised. Therefore, one is forced to depend on theoretical considerations which would provide such criteria of aggregation that would minimize the distortion of the

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[18] Ibid., p. 208.

"true" solution. This leads to the study of some formal aspects of the question of aggregation.

3. A Formal Study of Aggregation in Input-Output Framework

The material in this section is not original. But the section brings together and give a uniform treatment to ideas which are scattered in bits throughout the literature. No particular attention is given to the degree of rigor in introducing the subject, the presentation of the substance of the matter being the primary objective. In this sense also this chapter to some extent departs from the pattern common in the printed literature on aggregation. It is hoped that by doing so the substantive importance of the problem is underlined. Specific references to source materials are found in the next few footnotes.

The criteria of aggregation of sectors of an economy can be stated in precise mathematical terms within the framework of input-output analysis. It is convenient to study the problem with respect to the aggregation of two generic sectors at first and then generalize the result for the case of aggregating any m-member subset of the original n sectors $(m < n)$.

A. Aggregation of Two Sectors

Suppose a 5-sector input-output matrix is available for an economy. Let the accounts be presented on a net basis, that is, $x_{ii} = 0$ for all i. This is displayed in Table 5.

TABLE 5

ACCOUNTING SCHEME FOR DESCRIPTION OF INTERINDUSTRY TRANSACTIONS

Producing Sector	Purchasing Sector					
	1	2	3	4	5	Total
1	. . .	x_{12}	x_{13}	x_{14}	x_{15}	X_1
2	x_{21}	. . .	x_{23}	x_{24}	x_{25}	X_2
3	x_{31}	x_{32}	. . .	x_{34}	x_{35}	X_3
4	x_{41}	x_{42}	x_{43}	. . .	x_{45}	X_4
5	x_{51}	x_{52}	x_{53}	x_{54}	. . .	X_5
Total	X_1	X_2	X_3	X_4	X_5	$\sum_{i=1}^{5} X_i$

Now suppose sectors 3 and 4 are to be combined into one sector identified as sector (3 + 4). Then the following matrix is obtained:

TABLE 6

CONSOLIDATED SCHEME OF INTER-INDUSTRIAL TRANSACTIONS

Producing Sector	Purchasing Sector				
	1	2	3 + 4	5	Total
1	. . .	x_{12}	$x_{23} + x_{24}$	x_{15}	X_1
2	x_{21}	. . .	$x_{23} + x_{24}$	x_{25}	X_2
3 + 4	$x_{31} + x_{41}$	$x_{32} + x_{42}$	$x_{34} + x_{43}$	$x_{35} + x_{45}$	$x_3 + X_4$
5	x_{51}	x_{52}	x_{53} x_{54}	. . .	X_5
Total	X_1	X_2	$X_3 + X_4$	X_5	$\sum_{i=1}^{5} X_i$

Note that in Table 6 the intra-industry transactions for the newly-formed sector (3 + 4) is not zero. A comparison of Table 5 and Table 6 reveals that this feature is due to the nature of consolidation undertaken. In order to maintain the set of all accounts in the table on a net basis it is necessary to suppress the intra-industry account of sector (3 + 4). This will yield Table 7:

The problem of aggregation in input-output analysis boils down to a consideration of the manner in which the inverse matrix

TABLE 7

CONSOLIDATED SCHEME OF INTERINDUSTRIAL TRANSACTIONS REDUCED TO A NET BASIS

Producing Sector	Purchasing Sector				
	1	2	3 + 4	5	Total
1	. . .	x_{12}	$x_{13}+x_{14}$	x_{15}	X_1
2	x_{21}	. . .	$x_{23}+x_{24}$	x_{25}	X_2
3 + 4	$x_{31}+x_{41}$	$x_{32}+x_{42}$	. . .	$x_{35}+x_{45}$	X_3+X_4
5	x_{51}	x_{52}	$x_{53}+x_{54}$	. . .	X_5
Total	X_1	X_2	X_3+X_4	X_5	$\sum_{i=1}^{5} X_i - (x_{34}+x_{43})$

$(I - A)^{-1}$ changes. But the latter depends ultimately on the coefficients of production a_{ij} (the elements of matrix A). Therefore, in relation to this discussion, one may ask: In what ways, if any, are the a_{ij} computed from Table 7 related to those calculated from Table 5?

Recall that $a_{ij} = \frac{x_{ij}}{x_j}$. It is seen that those a_{ij}, computed from Table 7, which do not involve the newly-formed sector (3+4), are identical with the corresponding ones computed from Table 5.

For example $a_{12} = \frac{x_{12}}{x_2}$ from both tables. However, those a_{ij} that involve sector (3+4), which constitute the ones obtained on the basis of the entries in column (3+4) and row (3+4) in Table 7, are as follows:

$$a_{(3+4)1} = \frac{x_{31} + x_{41}}{x_1} = \frac{x_{31}}{x_1} + \frac{x_{41}}{x_1} = a_{31} + a_{41}$$

(6.3) $$a_{(3+4)2} = \frac{x_{32} + x_{42}}{x_2} = \frac{x_{32}}{x_2} + \frac{x_{42}}{x_2} = a_{32} + a_{42}$$

$$a_{(3+4)5} = \frac{x_{35} + x_{45}}{x_5} = \frac{x_{35}}{x_5} + \frac{x_{45}}{x_5} = a_{35} + a_{45}$$

$$a_{1(3+4)} = \frac{x_{13} + x_{14}}{x_3 + x_4} = \frac{a_{13}x_3 + a_{14}x_4}{x_3 + x_4}$$

$$= a_{13}\left(\frac{x_3}{x_3 + x_4}\right) + a_{14}\left(\frac{x_4}{x_3 + x_4}\right)$$

or

(6.4) $$a_{1(3+4)} = a_{13}w_3 + a_{14}w_4$$

where

$$w_3 = \frac{x_3}{x_3 + x_4}$$

and

$$w_4 = \frac{x_4}{x_3 + x_4} .$$

Similarly

(6.5) $$a_{2(3+4)} = a_{23}w_3 + a_{24}w_4$$

$$a_{5(3+4)} = a_{53}w_3 + a_{54}w_4$$

The results may be expressed more conveniently:

From (6.3):

(6.6) $$a_{(3+4)j} = a_{3j} + a_{4j} \qquad (j = 1,\ 2,\ 5)$$

and from (6.4) and (6.5)

(6.7) $$a_{i(3+4)} = a_{i3}w_3 + a_{i4}w_4 \qquad (i = 1,\ 2,\ 5)$$

Equations (6.6) indicate that some of the a_{ij} in the consolidated matrix are simply the sum of the a_{ij} in the component sectors of the newly-formed (aggregative) sector. Equations (6.7) indicate that some of the a_{ij} in the consolidated matrix are a weighted sum of the a_{ij} of the component sectors. This shows that the set of coefficients in the consolidated matrix cannot be obtained by simply adding the production coefficients in the component sectors. In fact, some of the a_{ij} depend upon the level of output in the component sectors as well as the production coefficients in these sectors. This can be seen from (6.7) if it is remembered that

(6.8) $$w_j = \frac{x_j}{x_3 + x_4} \qquad (j = 3,\ 4)$$

Since in general x_3 and x_4 are assumed to vary independently, it follows that $a_{i(3+4)}$ may vary significantly. This contradicts the stability requirement associated with the production coefficients.

There are, however, two conditions under which the stability of $a_{i(3+4)}$ is guaranteed. Either condition suffices for this result.

(1) If $a_{i3} = a_{i4}$, then no change in the weights resulting from changes in the proportions in which x_3 and x_4 are demanded will affect the aggregate coefficient. This shows that sectors can be aggregated on the basis of similar input coefficients (or cost structures).

(2) If x_3 and x_4 always change in fixed proportions, the weighted average of the input coefficients will be the same, regardless of differences in its components. To show this, let $x_3 = \lambda x_4$. Then from (6.7) and (6.8):

$$a_{i(3+4)} = a_{i3} \frac{x_3}{x_3 + x_4} + a_{i4} \frac{x_4}{x_3 + x_4}$$

$$= a_{i3} \frac{\lambda x_4}{\lambda x_4 + x_4} + a_{i4} \frac{x_4}{\lambda x_4 + x_4}$$

$$= a_{i3} \frac{\lambda}{1+\lambda} + a_{i4} \frac{1}{1 + \lambda} \tag{6.9}$$

Equation (6.9) shows that when x_3 and x_4 are proportional then the production coefficients for the aggregative sector (3 + 4) is stable regardless of the relative size of the component coefficients a_{i3} and

a_{i4}. It can be concluded that sectors can be aggregated on the basis of output proportionality (or complementarity). These two rules established for the aggregation over two sectors can easily be extended to be made applicable to aggregation over m sectors of an n-sector input-output matrix ($m < n$). This will be discussed next.

B. Aggregation of Several Sectors

Let there be an economy consisting of n producing sectors indexed by 1, 2, ... , n, and a final demand designated by 0. (See Table 8 column and row 0) Suppose $(n - m)$ sectors of this economy are to be aggregated into one sector. Since the numbering of sectors is arbitrary, it is convenient to renumber the sectors such that those to be aggregated are the last $(n - m)$ sectors, the first $m - 1$ sectors remaining unchanged. Designate the aggregative sector by M. Table 8 summarizes the setup:

Table 8 can be thought of as being the result of consolidation of an n-sector matrix.[19] The relations between such an n-sector

[19] In fact, the original matrix would have $(n+1)$ rows and columns, one for the final demand sector and n for the intermediate demand sectors. Depending upon whether reference is made to an open or a closed Leontief model, one would exclude or include the final demand sector (indexed by 0) among those for which a set of production coefficients are defined. In a general level of treatment such as this one, no distinction is necessary between the two formulations of the model.

TABLE 8

Producing Sector	Purchasing Sector			
	0	1 . . . m - 1	m to n	Total
0	x_{00}	$x_{01} \cdots x_{1(m-1)}$	x_{0M}	X_0
1	x_{10}	$x_{11} \cdots x_{2(m-1)}$	x_{1M}	X_1
$\vdots$	$\vdots$	$\vdots \quad \vdots$	$\vdots$	$\vdots$
m - 1	$x_{(m-1)0}$	$x_{(m-1)1} \cdots x_{(m-1)(m-1)}$	$x_{(m-1)M}$	X_{m-1}
m to n	x_{M0}	$x_{M1} \cdots x_{M(m-1)}$	x_{MM}	X_M
Total	X_0	$X_1 \cdots X_{m-1}$	X_M	

matrix and Table 8 can be stated as follows:

(6.10) $$x_{Mj} = \sum_{i=m}^{n} x_{ij} \qquad j = 0, 1, 2, \ldots, m-1$$

(6.11) $$x_{iM} = \sum_{j=m}^{n} x_{ij} \qquad i = 0, 1, 2, \ldots, m-1$$

(6.12) $$x_{MM} = \sum_{j=m}^{n} \sum_{i=m}^{n} x_{ij}$$

(6.13) $$x_M = \sum_{k=m}^{n} x_k$$

Before going further it should be noted that Table 8 records the interindustry transactions on a <u>gross</u> basis ($x_{ii} \neq 0$). It will be shown in section 4 of this chapter that there exists a simple transformation between production coefficients on net and production coefficients on a gross basis. Therefore, the present discussion ignores the distinction between net and gross interindustry transactions.

Now the information in Table 8 and equations (6.10) - (6.13) can be used to define a set of production coefficients a_{ij} for the aggregated matrix in Table 8 to be related to the production coefficients obtainable from the original, non-aggregated matrix. The following relations are true:

$$(6.14) \qquad a_{ij} = \frac{x_{ij}}{x_j} \qquad i, j = 0, 1, 2, \ldots, m-1$$

$$a_{Mj} = \frac{x_{Mj}}{x_j}$$

$$= \frac{\sum_{i=m}^{n} x_{ij}}{x_j}$$

$$= \frac{x_{mj}}{x_j} + \frac{x_{(m+0)j}}{x_j} + \ldots + \frac{x_{nj}}{x_j}$$

or

$$(6.15) \qquad a_{Mj} = a_{mj} + a_{(m+1)j} + \ldots + a_{nj} \qquad (j = 0, 1, \ldots, m-1)$$

Equation (6.14) states that for sectors not aggregated the production coefficients remain unchanged. Equation (6.15) shows that the input requirements of each sector from the aggregated sectors is equal to the arithmetic sum of the input requirements from the individual component sectors.

From Table 8 and equations (6.11) and (6.13) the following can be derived.

$$a_{iM} = \frac{x_{iM}}{x_M}$$

$$= \frac{\sum_{j=m}^{n} x_{ij}}{\sum_{k=m}^{M} X_k}$$

$$= \frac{\sum_{j=m}^{n} \frac{x_{ij}}{X_j} X_j}{\sum_{k=m}^{n} X_k}$$

or

$$a_{iM} = \frac{\sum_{j=m}^{n} a_{ij} X_j}{\sum_{k=m}^{n} X_k}$$

(6.16) $$= \sum_{j=m}^{n} a_{ij} w_j \qquad (i = 0, 1, 2, \ldots m-1)$$

where

(6.17) $$a_{ij} = \frac{a_{ij}}{x_j} \quad \text{and} \quad w_j = \frac{X_j}{\sum_{k=m}^{n} X_k} \quad (j = m, \ldots, n)$$

Equation (6.16) states that the production coefficients in a sector which is an aggregate of several elementary sectors are a weighted average of the production coefficients of the component sectors. The weights reflect the relative importance of each component sector as measured by the level of its output. The higher the level of output of an elementary sector, the greater the influence of that sector in the determination of the production coefficients of the aggregative sector.

Observe that the results (6.6) and (6.7) are special cases of (6.15) and (6.16), respectively.

From (6.16) and (6.17) it is seen that the production coefficients a_{iM} for the aggregative sector M depend not only upon the production coefficients of the component sectors but also on the relative levels of output of these sectors. Since these output levels in general vary independently of one another then the a_{iM} calculated from one "product mix" will be different from that calculated for a different product mix. In other words, the assumption of stability of production coefficients with respect to the levels of output in various sectors is violated.

As in the case of the two-sector aggregation there are two conditions (each sufficient by itself) under which the stability assumption is satisfied:

(1) When a_{ij} are equal in the various elementary sectors to be aggregated then their weighted average is the same, regardless of the values of the weights.

(2) When the outputs of the sectors to be aggregated vary in fixed proportions with respect to one another, a_{ij} has a fixed value,

regardless of the specific values of output in each component sector. To show this let

$$X_j = \lambda_j X_m \qquad (j = m,\ m+1,\ .\ .\ .\ .\ ,\ n) \tag{6.18}$$

Substitution for X_j and X_k in (6.17) yields:

$$w_j = \frac{\lambda_j X_m}{\sum_{k=m}^{n} \lambda_m X_m} \qquad (j = m,\ .\ .\ .\ .\ ,\ n)$$

$$= \frac{\lambda_j}{\sum_{k=m}^{n} \lambda_k} = \beta_j \qquad (j = m,\ .\ .\ .\ .\ ,\ n) \tag{6.19}$$

Substitute from (6.19) in (6.16) to get

$$a_{iM} = \sum_{j=m}^{n} a_{ij}\ \beta_j \qquad (i = 0,\ 1,\ 2,\ .\ .\ .\ .,\ m-1) \tag{6.20}$$

where β_j are constants defined by (6.19).

The constance of a_{iM} in (6.20) depends on the truth of the assumption (6.18) which states that the "product mix" among sectors to be aggregated is characterized by fixed proportions between the output of any two sectors.

This concludes a formal study of the problem of aggregation of sectors in input-output analysis. Two principles of aggregation have emerged from the above theoretical considerations; these are repeated here for future reference:

(1) Sectors that are similar with respect to their production coefficients can be aggregated into one sector.

(2) Sectors whose outputs vary in fixed proportions with respect to one another can be aggregated into one sector.

It is interesting to note that these criteria of aggregation were established by Samuelson with reference to a much more general setup than input-output analysis prior to the popularization of the latter:

> Broadly speaking, we replace a number of variables by a single variable under two diametrically opposite conditions. In the first, the variables have each the same effect (except possibly for scale differences which disappear upon redefinition) upon all of the economic functions under discussion. In this case they can be summed and treated as one. Thus, we might define as the same commodities all goods which have exactly the same influence on consumption preference fields and production functions, which are so to speak infinitely substitutable. . . .
> At the other extreme we combine variables which bear an invariant, 'perfectly joint' relationship to each other. A notable example is provided by the classical 'dose' of labor and capital applied to land. . . . [20]

Prior to the development of input-output analysis such theoretical propositions were of interest only to economic theorists and were thought of having little practical significance in relation to problems of data collection and industrial classification. Today this

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[20] Samuelson, <u>Foundations . . .</u> , pp. 144-145.

principle has operational significance in the economic science--it serves as a guide to empirical economists who, until recently, relied on arbitrary schemes for classification of commodities and economic activities. Indeed this state of affairs had to await the development of a conceptual framework oriented toward a statistical analogue with its unavoidably systematic and consistent classificatory schemes. That is why neither the purely conceptual Walrasian general equilibrium nor the purely descriptive works of the early empiricists could be anything but a "compartment" of the economic science--unable to absorb much of the developments that went on in the science as a whole. Leontief has succeeded in building a bridge between theoretical and empirical economics, making each depend on the other and the economic science as the perpetual interaction between the two.[21]

4. Aggregation and the Problem of Intra-Industry Transfers

It was seen in section 1 of this chapter that in order to keep an input-output matrix on a net basis the intra-industry transfers must

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[20] Along with other works by Leontief reference should be made to his article "Introduction to the Theory of the Internal Structure of Functional Relationships," Econometrica, October, 1947. Here he studied the method of functional separability when confronted with a large number of economic variables. The mathematical problem involved is that of grouping a set of functionally interdependent variables in such a way that functions within an overall function be formed. The dividing of an overall function into a set of component functions is the mathematical equivalent to the division of the economy into a number of sectors.

be systematically "netted out." It was pointed out that the complexities arising out of the distinction between net and gross measurement could be ignored because of the existence of a simple transformation between the production coefficients related to the two. This transformation is now developed.

Consider $(I - A)$ and $(I - A)^{-1}$ from equations (5.35) and (5.36) of Chapter V. Suppose these are computed on a net basis. What modifications are necessary in order to make these two matrices applicable to the case of gross measurement?

Let X_j designate the output of sector j on a net and Z_j on a gross basis. Then

$$X_j = Z_j - x_{jj} \qquad (j = 1, 2, \ldots, n) \tag{6.21}$$

where x_{jj} is the volume of intra-industry transfers for sector j. From (6.21) and the definition of production coefficients it follows that

$$a_{ij} = \frac{x_{ij}}{X_j} \qquad (i \neq j) \tag{6.22}$$

$$b_{ij} = \frac{x_{ij}}{Z_j} \qquad (i \neq j) \tag{6.23}$$

where a_{ij} and b_{ij} are the production coefficients on a net and a gross basis, respectively. Observe that

$$b_{ij} = \frac{a_{ij} X_j}{Z_j}$$

$$= \frac{a_{ij} (Z_j - x_{jj})}{Z_j}$$

$$(6.24) \qquad = a_{ij} (1 - b_{jj}) \qquad (i \neq j)$$

Equation (6.24) establishes a relationship between the production coefficients on a net and on a gross basis. Given the "net" coefficients a_{ij} one can obtain the entire set of "gross" coefficients b_{ij} by multiplying each a_{ij} by the factor $(1 - b_{jj})$.

The more significant problem, however, is the manner in which $(I - A)^{-1}$ is to be modified. This is so because the computation of a large size matrix is a complicated and costly task. It would be extrenely convenient if the inverse matrix based on gross data could be derived from that based on net data by a simple rule than having to go through the entire computational scheme separately. This can be done.

Let A define a matrix with elements a_{ij} and let $a_{ij} = 0$ for $i = j$. Further, let $[b_{jj}]$ define a diagonal matrix with b_{jj} as its diagonal elements. Then equation (6.24) can be expressed as follows:

$$(6.25) \qquad [b_{ij}] - [b_{jj}] = A(I - [b_{jj}])$$

which upon transposition becomes

$$[b_{ij}] = [b_{jj}] + A(I - [b_{jj}]) \tag{6.26}$$

This implies that

$$\begin{aligned} I - [b_{ij}] &= I - [b_{jj}] - A(I - [b_{jj}]) \\ &= I(I - [b_{jj}]) - A(I - [b_{jj}]) \\ &= (I - A)(I - [b_{jj}]) \end{aligned} \tag{6.27}$$

It follows from (6.27) that

$$\begin{aligned} (I - [b_{ij}])^{-1} &= (I - [b_{jj}])^{-1}(I - A)^{-1} \\ &= [\frac{1}{1 - b_{jj}}](I - A)^{-1} \end{aligned} \tag{6.28}$$

since the inverse of a diagonal matrix is another diagonal matrix with its diagonal elements being the inverse of those in the original matrix. Let $[A_{ij}] = (I - A)^{-1}$ and $[B_{ij}] = (I - [b_{ij}])^{-1}$. Then equation (6.28) can be written

$$[B_{ij}] = [\frac{A_{ij}}{1 - b_{jj}}] \tag{6.29}$$

Equation (6.29) shows that given A_{ij}, the elements of the inverse matrix computed on a net basis, then B_{ij}, the elements of the inverse matrix on a gross basis, can be obtained.

Transformation (6.29), in addition to its immense practical value in computational works, is of theoretical interest because it shows that whatever propositions are established with regard to the models that assume intraindustry transfers to be zero can easily be modified to be applied to the case of nonzero intraindustry transfers.

5. Some Theoretico-Empirical Aspects of Aggregation

The universality of the aggregation problem in economics is well expressed by Chenery and Clark:

> All economic theory is based on the assumption of uniformity in the characteristics and behavior of certain basis units, whether they be single households, firms, industries, consumers as a whole, or national economies. Such uniformity is sometimes predicted on the assumption of similar behavior by each of the units in the group, as in Marshall's representative firm; in other cases a predictable aggregate reaction is expected from widely different individual responses, as in the Keynesian consumption function. . . .[22]

Balderston and Whitin observe that "in economics, the most basic unit in micro, ad well as macro, theory are aggregates. . . . From the standpoint of aggregation, the difference between micro and macro economics is one of degree rather than of kind."[23]

Further on, the same authors note that "the general problem of aggregation from microeconomic to macroeconomic models has been

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[22]Chenery and Clark, pp. 34-35.

[23]J. Balderston and Whitin, "Aggregation in the Input-Output Model," Morgenstern, p. 80.

discussed in literature, although not to an extent commensurate with its importance."[24]

One is lead to suspect that the recent interest in the aggregation problem is due to the shift of emphasis from purely theoretical constructions to such models that can be given a corresponding empirical analogue. In this regard Chenery and Clark remark that "in its first theoretical formulation, the Leontief sector was, like the Marshallian or Walrasian industry, assumed to be composed of plants producing a single homogeneous product by similar techniques. In transforming this formal model into an empirical tool, the problem of aggregating all activities into sectors has assumed great importance."[25] (Emphasis added, M.M.)

Empirical works in highly aggregated measures and the methods applied in such works has come under attack by a number of economists.

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[24] Ibid., p. 81; the authors provide the following references: Dresch, R. W., "Index Numbers and the General Economic Equilibrium," Bulletin of American Mathematical Society, XLIV, Feb., 1938, 134-141. Klein, R. L., "Macroeconomics and the Theory of Rational Behavior," Econometrica, XIV, Aug., 1957, 93-108. Klein, R. L., "Remarks on the Theory of Aggregation," Econometrica, XIV, October, 1946, 303-313. May, K., "Technological Change and Aggregation," Econometrica, Jan. 1947, pp. 41-63.

[25] Chenery and Clark, p. 35.

> During recent years, highly aggregative economic models have been constructed and efforts have been made to observe the interactions among a few tremendous aggregates (such as Gross National Product, National Income, etc.). Attempts to discover significant correlations between the movements of these aggregates have been made, the use of multiple correlation analysis itself tending to limit the number of variables. Thus almost all detail is lost in these models and it is no mean feat to attach any economic meaning to the heterogeneous aggregations that these models bring forth.[26] (Emphasis added, M.M.)

Commending economic theorists for their development of a "remarkably well-organized framework" for the analytical manipulation of systems involving a very large number of distinct but interrelated elements, Leontief adds that "one of the paradoxical aspects of its [i.e., economic theory's] present situation is that, instead of guiding empirical research in the direction of differentiated sets of primary data, the theory itself seems to be reverting to grossly aggregative formulation."[27]

Input-output analysis is a framework that remedies the problems referred to above. It is designed to provide theoretical "empty boxes" for a significant amount of primary data. That is due to the fact that it is formulated in terms of a large number of sectors in the economy. It is true that the elementary sectors themselves

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[26] Balderston and Whitin, p. 80.

[27] Leontief, Studies in . . . , p. 6.

are aggregates, but there is room for considerable flexibility for further aggregation within the system. Thus the problem of aggregation becomes very significant in input-output analysis. This stands in sharp contrast to the econometric models of the economy which are formulated in terms of high-level aggregates from the outset, thus goind away with the problem of changing degrees of aggregation within the model altogether.

Within the framework of input-output analysis the aggregation problem has a theoretico-empirical character because it can be formulated formally on theoretical grounds but the theoretical principles derived from the formal analysis must be checked continually against the empirical difficulties that arise in the implementation of the model. Consider, for example, the most basic notion in input-output analysis; namely, "sector." Some have already been discussed.[28] Also a formal study of the problem of aggregation of sectors into larger sectors was presented in section 3 of this chapter. Two criteria of aggregations were proposed there: aggregation on the basis of complementarity of outputs among the sectors to be aggregated, and aggregation on the basis of similarity of input structures.

In the actual implementation of the theoretical model many modifications become necessary. Strict adherence to the theoretical

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[28] See sections 1 and 2, Chapter VI.

criteria is impossible. These criteria should be regarded as guides to empirical work, not as precise rules to be followed. Departure from theoretical criteria is forced upon the investigator by the richness, variety, and existence of "borderline cases" in empirical reality.

In classifying industries for input-output analysis one is tempted to undertake a very fine classification with the objective of adhering closely to the criterion that the output of each sector must be homogeneous. In general, the larger the number of sectors, the lower the degree of heterogeneity of the products of the same group. But this lower degree of heterogeneity also has the unfortunate consequence of multiplying the possibilities of technical substitution between products originating in different sectors. Further, as shown at the end of section 1 in this chapter as the number of sectors grows the assumption of additivity[29] grows less and less tenable. Ignoring this last difficulty, Malinvaud notes that:

> . . . The delimitation of sectors must present some kind of compromise between two requirements: making the products of the same group as substitutable as possible, and, at the same time, avoiding that products of different sectors be alternatively used in certain industrial processes.[30]

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[29]See section 1, Chapter VI for the statement of the additivity assumption.

[30]Malinvaud, p. 194.

Malinvaud cities fuel as an illustration of the difficulties involved. The specific differences between coal, petroleum, manufactured gas, and electricity would imply that they be separated in different sectors. But, on the contrary, the possibilities of technical substitution between them require that they be considered as products of the same industry. In such cases generally the present and future uses of the model can serve as a guide to classification. There are many instances in which the ultimate choice with regard to <u>all</u> aspects of a classificatory scheme depends on the purpose at hand, even though <u>many</u> aspects of the problem are determined by the theoretical guidelines discussed earlier.

Balderston and Whitin express similar views. Nevertheless it is worthwhile to quote them in full:

> Coefficients of production may appear to be non-constant as a result of aggregation, even if the elements of the more detailed classification were all industries whose input coefficients were in fact constant; if the aggregation is too coarse, coefficients will represent averages of meaningless groupings. However, if the aggregation is too fine, substitutions in production-processes may destroy the constancy of the technological coefficients. We cannot hope to avoid both these sources of error, but should try to strike a balance between them.[31]

The authors add that the problem of destroying the constancy of coefficients due to "too fine" a classification can safely be ignored since

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[31] Balderston and Whitin, p. 103.

"solvable systems are more likely to be too highly aggregated."[32] The practical choice is thus a compromise between the theoretical requirements and the empirical expediencies! To what extent this compromise can be yielded to before the usefulness of the model is seriously impaired is itself an empirical question and cannot be resolved on purely theoretical grounds. In a later chapter a selective survey of the works in this area will be presented. At this point some general propositions with regard to possible errors due to aggregation can be made:

It is clear that each industry in the short-run has a maximum possible level of output. The necessary output of each industry is given by the solution of the input-output system. Let x_i^0 and x_i designate the capacity output and necessary output for the i-th industry, respectively. A solution to the input-output system is called feasible if

$$x_i \leq x_i^0 \qquad (i = 1, 2, \ldots, n) \tag{6.30}$$

It is possible that a solution $\bar{x}_i$, $(i = 1, 2, \ldots, n)$, is feasible according to (6.30) but not feasible in reality! Or it may be that a solution $\bar{\bar{x}}_i$, $(i = 1, 2, \ldots, n)$, is not feasible according to (6.30) but actually feasible. This can happen because the solutions depend

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[32] *Ibid.*

to some extent on the assumptions made concerning substitutability. Balderston and Whitin present the problem concisely.[33]

> Assume that there exists perfect substitutability among components of each aggregate and also assume complete lack of substitutability among aggregates. In so far as the former assumption exaggerates the degree of substitutability, solutions might be thought feasible which were not in fact attainable. The latter assumption, in underestimating the degree of substitutability, may indicate that some solutions are not feasible which in fact are attainable. As the amount of aggregation increases, the former assumption is likely to play a more important part than the latter. Thus, highly aggregative systems are likely to overestimate the attainable levels of production and consumption. On the other hand, systems involving much less aggregation are likely to underestimate the potentiabilities of the economy.

The same authors provide an example which illustrates the point: An increased level of activity in the iron and steel industry might necessitate a greatly increased production of coal. If coal is classified along with a number of other substances as in an aggregate called fuel, then the problem of increasing coal production to the necessary level might be obscured. "As a result the aggregative analysis might lead us to attempt attainment of impossible ends. In

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[33] *Ibid.*, p. 94.

fact it may defeat one of the chief applications [of input-output analysis], the discovery of potential bottlenecks."[34]

It is generally desirable to discover where and when shortages are likely to occur when a given economic program is the goal. If the output of each industry were represented by a different variable the solution to the system could be compared with the capacity of each industry and the existence of shortages could be detected. When several industries are aggregated into one, however, such information in general is lost unless the combined industries are strictly complementary, in which case the total output for the combined sector can be translated into the output of each component sector by means of the proportionality of outputs. As an example, suppose that large quantities of a certain type of fractional-horsepower electric motor were essential to airplane production. These motors might be grouped with a number of electric parts and form a very small portion of the aggregate. If increased airplane production were attempted, the amount of motors needed might exceed the amount that could be produced, but the aggregate figure would not point out the shortage. In such cases aggregation is not permissible unless the components of the aggregate

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[34] Ibid., p. 92; for the application of input-output analysis to be problem of "bottlenecks" see section 3 of Chapter VII.

represent either an approximately constant proportion of the aggregate or that the proportions vary in some predictable fashion.

Identification of "crucial" industries in the economy in order to avoid their being aggregated into larger sectors depends, to a large extent, upon the familiarity of the investigator with the technical and natural conditions of production. But the overriding factor in this regard is the purpose of the analysis. One can speak of an item being "crucial" only in relation to a specified goal and within a given frame of reference. An industry which is "crucial" for one program of final demand may not be so for a different program.

As Balderston and Whitin have noted, "for some specific purposes it is a trivial matter to select a good unit of aggregation. As the purpose becomes more general, one may expect the choice of basic units to be more difficult."[35] Professor Leontief writes that "the question of aggregation represents essentially a special aspect of the more general problem of the classification of industries and of relevant distinction between different sectors of the national economy in general."[36]

Classification of industries necessarily involves purpose. This is in opposition to the purely descriptive viewpoint according to

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[35] Ibid., p. 81.

[36] Leontief, The Structure . . . , p. 208.

which classification may be conceived independently of the possible uses of the data. "It is now accepted that 'measurement' without theory implies some more or less unavowed idea about the future usefulness of the figures. In order to make these ideas as explicit as possible, it is better to consider directly the model in which the data will eventually be inserted."[37]

The input-output model goes far in the direction of providing a general framework for industrial classification. But the existing practices continue to follow the traditional lines. Balderston and Whitin note that "many industrial classifications had their origins in medieval times, although the nature of the activities may have changed considerably. It may prove desirable to gather data for the economy on a basis that does not correspond well to the existing industry structure."[38] Thus the absence of a theoretical framework implies, in practice, the presence of outdated and/or arbitrary criteria of classification.

As an example of how theoretical criteria of classification implied by the input-output model can guide the empirical economist in the collection and classification of facts the methods of "vertical," "horizontal," and "partial horizontal" aggregation will be discussed.

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[37] Malinvaud, p. 190.

[38] Balderston and Whitin, p. 99.

A. Vertical and Horizontal Aggregation

Suppose the output of industry A is wholly absorbed as input by industry B, and that there are no substitutes for A's output that B can use. This would amount to strict proportionality between the outputs of the two industries. Rule (2) for aggregation of industries[39] is applicable in this case and industries A and B could be grouped together. Holzman calls this "vertical aggregation."[40] A third industry could be added if it were related to B in the same way that B is related to A.

For example, iron ore, pig iron, and steel ingots may be grouped together as "steel industry."

"Horizontal aggregation" is said to occur when products in the same stage of manufacture are grouped together in one industry. Either rule (1) or rule (2) must be appropriate here. That is, either the cost structure for the industries being aggregated must be similar or the product mix must be proportional. Similarity of cost structure is more likely to prevail in horizontal aggregation. For example, in the purification of minerals several processes are

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[39]See section 3.B, this chapter.

[40]Mathilda Holzman, "Problems of Classification and Aggregation," in Leontief, Studies in . . . , p. 330.

performed that are essentially similar for a variety of minerals. Similar equipment, use of power, labor, etc., characterize these processes. In general the horizontal aggregation is based on a similarity of processes, whereas vertical aggregation is based on the raw material used or output produced.

"Partial horizontal aggregation"[41] is based on similarity of cost structures with respect to <u>some</u> inputs. Suppose that a certain array of products had production functions such that each product used labor and machinery in the same ratio and that "labor" and "machinery" have been defined as separate inputs. Suppose other inputs used by each industry involved are needed in proportion different from those of labor and machinery. Thus the cost structures of the various industries in the given array are different from each other. However, if it were desired for analytical purposes to make use of the fact that each product consumed labor and machinery in the same ratio, one could do so by defining a new "fictitious industry."[42] The only inputs of this industry would be labor and machinery. The output would be the service of labor and machinery in performing the particular operation by which

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[41] <u>Ibid.</u>

[42] Leontief has developed the general mathematical conditions for defining a fictitious sector. See W. W. Leontief, "Introduction to the Theory of the Internal Structure of Functional Relationships," <u>Econometrica</u>, XV, October, 1947.

the products are made. Labor and machinery would be removed from the original input columns, and instead, the output of the new fictitious industry would be distributed to the products of each industry involved. Holzman gives the following example:

Suppose separate industries are defined for rayon, nylon, silk, and cotton hosiery in such a way that the only process common to all of them is knitting. Define a fictitious industry whose output is knitting and its inputs are knitting machines, operator labor, and energy. Assume that the input of knitting is the same regardless of the textile of which the stocking is made. Then the service, knitting, could be distributed to each of the hosiery industries proportionately to its output of stockings. At the same time, knitting machines, operator labor, and energy associated with the use of knitting machines would be eliminated from each industry's input column since these now constitute the input structure of the knitting industry whose services the hosiery industries buy.

Thus, partial horizontal aggregation can be applied whenever the production function of the products are similar except for the material used. The treatment of trade and transportation in the 1939 input-output study by Leontief follows this method of aggregation. With regard to the type of aggregation which is to be preferred Barna makes the following enlightening comment:

> Whether we use . . . horizontal or vertical integretion [read aggregation, M. M.], depends on the purpose for which the analysis is used. If, for instance, the main purpose is to investigate the effects of technological change and to attempt to forecast the results of inventions, it is advisable to avoid undue vertical integration, and instead, to combine parallel processes of production. This is so because inventions are likely to affect one process at a time in a chain of successive industrial processes and are likely to affect similar processes in the production of different commodities. It is well known that major inventions at the early stages of industrialization in the textile industry affected one process at a time and were separated by a considerable interval from each other. If this point were to be given emphasis we would, for instance, group the smelting of different non-ferrous metals into one industry, and the rolling of different metals into another, rather than all processes dealing with one metal as one industry, and those dealing with another metal as a second industry.[43]

Thus, the theoretical principles of aggregation of industries implied by the input-output model provide an approach to the study of specific features of the technology of the economic system. Aside from its use in the construction of the statistical analogue of the theoretical model, this knowledge is valuable in itself. Study of the technological process as a whole and as historico-social stream of phenomena is a neglected area. Most economic models take technology as datum. However as the economic science develops it can be expected that the discipline will attempt to "explain" the technological

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[43]Barna, "Classification and Aggregation in Input-Output Analysis," p. 181.

process rather than treating it as a datum. Various engineering disciplines have recorded much of the primary information about the different parts of the economy. It is necessary to develop a unified theoretical framework which would reflect the interdependence among the various components of the technological process as a whole. A systematic study of the technological process would have uses that would reach beyond its economic applications, even though the importance of the latter cannot be overestimated. Great strides can be made in preserving the ecological balances in nature if the technological process and its interaction with nature is studied systematically. The interaction of the technological process with the non-technological aspects of the social process, political, socio-psychological, and sociological, could be studied with more success if the technological stream were studied as a complex process with organically interrelated parts not as an arithmetic (or mechanical) sum of so many individual parts which may only have incidental (as opposed to fundamental) relationships with one another. Anthropologists are aware of the "explanatory" importance of technology in relation to the social mode of existence of men. The study of tools and other artifacts of a primitive culture is an important key to the "understanding" of that culture. Social scientists shy away from such undertaking in relation to modern society perhaps because they do not (and--pending the development of a unified framework--cannot) comprehend the overall technological process.[44]

The input-output model goes afr in the direction of pointing some avenues of research in technology. But since the model is designed to fit the need of economists, it cannot but serve as a conjecturally-drawn, preliminary map of an unexplored area.

B. Some Problems of Implementation

Input-output models are based on a set of balance relationships (or accounting identities) between the various sectors of the economy, as presented in Chapter IV. But the accounting scheme of Chapter IV presupposes an original delimitation of sectors. Also all the previous discussions on aggregation assume an already existing classification scheme. Indeed, aggregation is but reclassification and at the same time reducing the number of separate sectors.[45] Professor Leontief notes that "the question of aggregation represents essentially a special aspect of the more general problem of the classification of industries and of relevant distinction between different

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[44]The work of Veblen, Thorstein, may be regarded as an attempt in this direction. Specifically his The Instinct of Workmanship, New York: W. W. Norton and Co., Inc., 1964.

[45]Malinvaud defines aggregation as "the representation of a model by another, simpler, model." (Malinvaud, emphasis; see Malinvaud, p. 189.

sectors of the national economy in general."[46]

In this section some of the problems associated with preparation of the original input-output table (to be aggregated subsequently for practical use) are studied. No exhaustive survey is intended here. Rather, those aspects of these problems which have an important bearing on the question of classification and aggregation will be discussed.[47]

As shown in the preceding sections, the theoretical criteria of defining a sector are homogeneity of output and similarity of input structure. But, as already noted, practical difficulties render strict adherence to the theoretical criteria impossible. Precisely what is the nature of these "practical difficulties"?

The answer is given by Chenery and Clark: "In practice the most serious limitation on the system of classification is set by the availability of data--specifically, the classification used in a

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[46]Leontief, The Structure . . . , p. 208.

[47]For a detailed presentation of the problems of design and construction of U. S. input-output tables see W. D. Evans and M. Hoffenberg, "The Interindustry Relations Study of 1947," Review of Economics and Statistics, XXXIV, May, 1952. For the preparation of the Canadian tables see Canada, Bureau of Statistics, The Interindustry Flow of Goods and Services, Canada, 1949 , Ottawa: E. Cloutier, Queen's Printer, 1956, and Canada, Bureau of Statistics, Supplement to the Interindustry Flow of Goods and Services, Canada, 1949, Ottawa: E. Cloutier, Queen's Printer, 1956.

country's industrial census."[48]

In the United States the Standard Industrial Classification was developed for "use in connection with the collection, tabulation, and presentation of data supplied by establishments. An establishment is generally defined as a single physical location where business is conducted or where services or industrial operations are performed; for example, a factory, mill, store, mine, or farm. Where a single physical location comprises two or more units which maintain separate payroll and inventory records and which are engaged in distinct or separate activities for which different industry classifications are provided in the Standard Industrial Classification, each such unit shall be treated as a separate establishment. . . ."[49]

Establishment is used as the basic unit classified by an industrial classification because, typically being the basic unit of industrial operation, it is the basic unit of statistical data collection. It is the smallest unit within the firm for which the various industry statistics are available.[50]

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[48] Chenery and Clark, p. 138.

[49] The Technical Committee on Industrial Classification, Bureau of the Budget, Standard Industrial Classification Manual, Vol. I, Part I, 1.

[50] See W. R. Simmons, "The Elements of an Industrial Classification Policy," Journal of the American Statistical Association, September, 1953, pp. 435-436.

An industry is a group of establishments which have sufficient common characteristics that they may be grouped together for analytical purposes. Thus the establishments grouped together in one industry must have the same (homogeneous) output and similar input structures. However, "American enterprises have a tendency towards diversification. . . . It is not exceptional that an establishment produces substantial amounts of commodities which do not belong to the industry to which it is assigned."[51]

If an establishment produces two products, for example coke and chemicals, its classification depends on which of these two products constitutes the greater proportion of its gross value of production. If this were chemicals, all the output of the establishment would be classified to the chemical products industry. If coke came to constitute the larger proportion of the gross value of the output, the establishment would be reclassified to the products of coal industry.[52] Thus, an establishment is assigned to an industry according to its primary output (the output which is the primary source of

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[51] Shiou-Shuang Yan, Introduction to Input-Output Economics, New York: Holt, Rinehart, and Winston, 1969, p. 60.

[52] Canada, Bureau of Statistics, The Interindustry Flow of Goods and Services, Canada, 1949, p. 8.

revenues). It may have other outputs; these are called its secondary products.

But the existence of eatablishments with secondary products in an industry violates the assumption of homogeneity of output by each sector. In practice there have been three approaches to this problem:[53]

(1) The method used in reporting data in census publications is to keep all the secondary products in the output of the industry. This approach is useless for input-output models because of the heterogeneity in the products of the industries thus defined.

(2) The method used in the preparation of 1947 and 1958 United States input-output tables is to treat secondary products as if they had been sold by the producing industries to the primary industries. Each secondary product is allocated as a fictitious input to the industry for which it is primary, and simultaneously it is added to that industry's output. Thus, each input-output row at least contains all of the primary product, wherever produced, but it counts the secondary products as well.

(3) A third method, followed primarily in Japan, is to shift completely to a commodity classification. Each secondary product is subtracted from the output of the original establishments and is added

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[53]Chenery and Clark, p. 139.

to the industry for which it is primary. Correspondingly, an appropriate portion of the inputs of the original establishments must also be transferred to that industry's input column. "This transfer of inputs can be done only approximately by using the primary industry's input structure as a guide, since the basic input data collected from the establishments are not usually broken down on a product basis."[54]

The third method is most conforming with the assumptions of input-output model. The 1958 table shifted somewhat in the direction of the third method as compared with the 1947 table. This was done in cases where secondary products were an important part of the producer's output and considerably different from the primary products.

It is seen, therefore, that the classification of sectors in input-output models essentially follows the industrial classification already available when these tables began to be compiled. This is more due to the administrative and other considerations in the process of data collection than an inherent consistency of the existing classificatory schemes. In a later chapter the nature and use of the so-called "general purpose"[55] classification schemes will be studied.

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[54] _Ibid._

[55] R. C. Epstein, "A General-Purpose Classification for Manufacturing Industries," _Journal of the American Statistical Association_, March, 1935, p. 47.

6. Summary and Conclusion

This chapter presented and analyzed the nature of the aggregation and classification problem, using the input-output model of the previous chapters as a specific frame of analysis. Two theoretical propositions with regard to aggregation of industries were derived formally. These were the conditions homogeneity of product (or strict complementarity between a group of products) and the similarity of cost structures as basis for grouping industries together.

It was shown that the theoretical criteria derived by formal analysis should be treated as guides in empirical works not as rules to be followed precisely.

Some technological aspects of the aggregation problem were analyzed. Specifically, the so-called vertical and horizontal aggregation were discussed.

It was shown that the classification adopted in a special situation depends, to a large extent, on the purpose at hand. A classification scheme appropriate for one set of problems may be useless for another.

This chapter may be concluded with a list of criteria that can be used for the evaluation of a classification system:[56]

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[56]See Balderston and Whitin, p. 97.

1. the appropriateness of the scheme for the purpose at hand;

2. the degree to which certain invariant relationships between the components of the various aggregate figures are maintained;

3. the amount the model is simplified;

4. the accuracy of the solution of one aggregated system of equations relative to the solution obtained for more detailed systems.

CHAPTER VII

SIGNIFICANCE OF THE AGGREGATION PROBLEM

The aggregative approach in economic analysis--both macro and micro--is due to a set of factors that relate to the internal development of the science. These factors, being of methological and historical nature, are best studied in a separate chapter. In this chapter a selected set of analytical concepts are reviewed in order to illustrate the immediate analytical results of working with a less aggregated and more detailed model.

It will be observed that some of the following analytical concepts are "aggregated out" of the Keynesian models while others are made less useful because they provide only overall measures for the economy as a whole, giving no information on the distribution of this measure in the various parts of the economy.

1. A Disaggregated Multiplier Analysis

The simplest version of the Keynesian model can be formulated linearly as follows:[1]

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[1] See Allen, Macroeconomic Theory . . . , pp. 114-115.

$$(7.1) \qquad Y = C + I_0$$

$$(7.2) \qquad C = cY + C_0$$

where Y, C and c are income, consumption, and marginal propensity to consume, respectively; and I_0 and C_0 are autonomous investment and autonomous consumption, respectively.

It follows from (7.1) and (7.2) that:

$$(7.3) \qquad Y(1 - c) = I_0 + C_0$$

Therefore:

$$(7.4) \qquad \Delta Y = \frac{1}{1 - c} \cdot \Delta(I_0 + C_0)$$

Equation (7.4) states that for an economy starting at equilibrium level of output a change in autonomous expenditure equal to $\Delta(I_0 + C_0)$ induces a change in income equal to $\frac{1}{1 - c} \cdot \Delta(I_0 + C_0)$.

Equation (7.4) may be decomposed as follows:

$$(7.5) \qquad \Delta Y = \frac{1}{1 - c} \Delta I_0 + \frac{1}{1 - c} \Delta C_0$$

In this form it states that the <u>ceteris paribus</u> change in income when investment changes by ΔI_0 is $\frac{\Delta I_0}{1 - c}$ and the <u>ceteris paribus</u> change in income when autonomous consumption changes by ΔC_0 is $\frac{\Delta C_0}{1 - c}$. The factor $\frac{1}{1 - c}$ is called "the multiplier" in the Keynesian model.

Its significance is well established in the literature and need not be expounded upon here.

An analogous procedure may be followed in relation to the input-output models. In fact, the reasoning behind the open Leontief system is similar to that of the Keynesian analysis. The "final demand" categories of the former correspond to the "autonomous expenditure" categories of the latter. In both systems the categories consist of one or more variables deliberately held "fixed" while the remaining variables assume values according to the specific structure of the model (as dictated by the values of the parameters of the system of equations describing the model). In the words of Leontief: ". . . The general logic of this [i.e., the siatic, open Leontief] procedure is essentially identical with that followed in somewhat less articulate form in different models of Keynesian multiplier analysis."[2]

The essential difference is that in input-output analysis a separate multiplier is computed for each sector of the economy. The multiplier for the j-th sector would measure the overall income effect of a given change in the demand for the product of that sector.[3]

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[2] Leontief, The Structure . . . , p. 206.

[3] The development of the multiplier analysis in relation to input-output models is almost entirely due to theoretical and empirical works of those interested in regional economics. Some references may be given: F. T. Moore, "Regional Economic Reaction

It is necessary to interpret the elements of the inverse matrix $(I - A)^{-1}$ encountered in the previous chapters. Let $(I - A)^{-1} = [A_{ij}]$. Then according to equation (5.36) Chapter V:

$$X = [A_{ij}]D \tag{7.6}$$

or

$$X_i = \sum_{j=1}^{n} A_{ij} D_j \qquad (i = 1, \ldots, n) \tag{7.7}$$

$$\frac{\partial X_i}{\partial D_j} = A_{ij} \tag{7.8}$$

Equation (7.8) states that ij-th element of the inverse matrix measures the number of units of the i-th product needed per unit of final demand of the j-th product. For instance, if i and j designate the chemical and agricultural industries, respectively, then A_{ij} is the amount of output of the chemical industry needed if the final demand for the output of the agricultural industry is to increase by one unit. For a given j, $[A_{1j}, A_{2j}, \ldots, A_{nj}]$ is a column vector which indicates the increase in output industries 1, 2, . . . , n if the final demand for the j-th industry is to increase by one unit.

Now let v_i represent the "value-added" portion of a dollar

Paths," American Economic Review, May, 1955, pp. 133-148; and G. Hildebrand and A. Mace, "The Employment Multiplier in an Expanding Industrial Market: Los Angeles County, 1940-1947," Review of Economics and Statistics, August, 1950, pp. 241-249.

receipt of industry i. v_i can be computed by expressing the net receipts of the sector (net after subtracting the total payments of the sector to the other endogenous sectors of the model from total receipts) as a proportion of total receipts.

The sum $\sum_{i=1}^{n} v_i A_{ij}$ measures the total value added--or, what is the same thing, the total income--generated in the economy due a unit increase in final demand for sector j.

To make the results more comparable with the Keynesian multiplier the "simple" income multiplier is defined as follows:[4]

$$M_j = \frac{\Sigma v_i A_{ij}}{v_j} \tag{7.9}$$

This states that if income in the j-th sector increases by one unit then income in the economy as a whole increases by M_j units.[5]

Thus, it is seen that for each of the n sectors of the economy it is possible to compute a multiplier which would give the increase in income for the economy as a whole as a reaction to a

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[4] Moore, p. 137.

[5] For a simple, 3-sector illustration and some numerical examples see, Shiou-Shuang Yan, Introduction to Input-Output Economics, New York: Holt, Rinehart, and Winston, 1969, pp. 65-73. Yan also evaluates some of the weaknesses of the "simple" multiplier and (following Moore) introduces the "full" income multiplier. These considerations are not of interest to the present discussion.

given increase in income of a particular sector. This additional information compares favorably with the overall Keynesian multiplier. This is a typical result of lowering the degree of aggregation in the model. In general, as the degree of aggregation decreases the amount of information provided by the solution of the model increases. At the same time the fact-absorbing capacity of the model increases; that is, on the input side more information is required by the model. Hence, disaggregation is a method of broadening the empirical base of an economic model.

2. Structural Analysis

In actual input-output tables many of the elements of inter-industry flow matrix, and, therefore, the corresponding coefficients of production, are equal to zero. Fertilizers, for instance, are not used in making steel, nor flour in the electric appliance industry. In practice the production coefficients that are sufficiently small (relative to a given standard of accuracy) are treated as zero.[6]

It may happen that a matrix with some $a_{ij} = 0$, after

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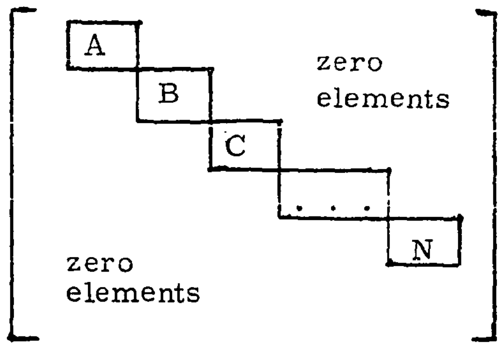
[6]Dorfman, Samuelson, and Solow warn that "structly speaking . . . zeros and small positive numbers are not the same thing." And the concept of the structure of a matrix is purely qualitative and non-quantitative. It depends on the pattern of positive and zero coefficients, and not on the size of these coefficients. See Dorfman, Samuelson, and Solow, p. 255.

appropriate transposition of columns and rows, is a quasi-diagonal[7] matrix, i.e., the position of its zero and non-zero elements is of the following pattern:[8]

(7.10)



where A, B, C, . . . , N are square matrices. The following is a specific example of such a matrix:

$$
(7.11)\qquad
\begin{bmatrix}
a_{11} & a_{12} & a_{13} & 0 & 0 & 0 \\
a_{21} & a_{22} & a_{23} & 0 & 0 & 0 \\
a_{31} & a_{32} & a_{33} & 0 & 0 & 0 \\
0 & 0 & 0 & a_{44} & 0 & 0 \\
0 & 0 & 0 & 0 & a_{55} & a_{56} \\
0 & 0 & 0 & 0 & a_{65} & a_{66}
\end{bmatrix}
$$

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[7] A diagonal matrix is defined as a square matrix for which $a_{ij} = 0$ for every $i \neq j$.

[8] For an elementary discussion on of "triangularization" of matrices see, Kogiku, pp. 23-24. Kogiku also discusses the concepts of "causal ordering" in matrices, a very useful notion in the study of the structure of a system of equations. An exhaustive

In this example the system of equations corresponding to the given matrix of coefficients can be decomposed into three independent subsystems, one corresponding to each "block" of coefficients in the above matrix. In economic terms this would mean that the economic system is not completely independent. Instead it consists of several independent subsystems such that changes in output, price, or technology within each subsystem affects the subset of variables that correspond to that subsystem, leaving the rest of the variables unchanged.

Another possible system of linear equations is one with a quasi-triangular matrix.[9] The following is a specific example:

$$(7.12) \qquad \begin{bmatrix} a_{11} & a_{12} & 0 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & a_{77} \end{bmatrix}$$

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discussion of decomposability of Leontief matrices may be found in Dorfman, Samuelson, and Solow, pp. 254-264.

[9] Since a triangular matrix is a special case of quasi-triangular matrices with only one coefficient in each block, no

In this case the system of equations corresponding to the given matrix is not decomposable into a number of independent subsystems as was the case with the quasi-diagonal matrix. However, another property is present.

Consider the system of equations:

$$(7.13) \qquad a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n = b_i \qquad (i = 1, 2, \ldots, n)$$

If the matrix of coefficients is quasi-triangular as in the example above then the values of x_1 and x_2 depend only on the coefficients appearing in the first two equations in the system:

$$(7.14) \qquad \begin{aligned} a_{11}x_1 + a_{12}x_2 &= b_1 \\ a_{21}x_1 + a_{22}x_2 &= b_2 \end{aligned}$$

The values of x_1 and x_2 found from here can be substituted in the following system to find the values of x_3, x_4, and x_5:

$$(7.15) \qquad \sum_{j=1}^{5} a_{ij}x_j = b_i \qquad (i = 3, 4, 5)$$

The procedure may be repeated for the remaining variables in a similar way.

In economic terms a quasi-triangular matrix of coefficients indicates that a given group of industries are independent of the rest

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separate discussion of it is deemed necessary.

of the economy but the rest of the economy is not independent of this group. That is, changes in the rest of the economy do not necessarily influence the value of the variables in this group of industries but any changes within this group necessarily brings about changes in the rest of the economy.

Thus the industries may be arranged in a hierarchical order with respect to their degree of independence. The group of industries that can be solved independently of the rest of the system may be called the zero-order system.[10] The system whose solution is contingent upon the solution of a zero-order group of industries has an order of one. If the solution of a system is contingent upon solving a first-order system, then it is called second order, and so on.

In general, the higher the order of the system to which a given industry belongs, the greater the number of industries that use the product of the given industry; that is, the more "basic" the given industry. Thus a high-order industry uses the inputs of few sectors but provides many sectors with its output. For example, steel is a high-order industry because its output is used by many sectors.

A low-order industry buys from many sectors but sells to only few. Generally the industries that are closer to the final

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[10] Kogiku, pp. 28-29.

demand tend to be of a lower order, selling to final demand and a few other sectors.

Finally the matrix of coefficients of a system of equations may have only one positive entry in each row and column with zeros in all other entries. As a specific example consider the following:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & a_{14} \\ a_{21} & 0 & 0 & 0 & 0 \\ 0 & 0 & a_{33} & 0 & 0 \\ 0 & a_{42} & 0 & 0 & 0 \end{bmatrix} \tag{7.16}$$

This is the case of complete specialization because each industry buys only from one industry and sells to only one industry.

It is seen that a disaggregated model of the economy reveals, upon examination of the matrix of coefficients, a set of interesting structural features of the system. This type of information is completely lost as the degree of aggregation increases to the limit of a one-industry model of which the Keynesian model is a specific example.

Further, it is evident that the structural characteristics of the economy displayed in the matrix of coefficients depend on the particular classification of industries adopted in the model. It is possible that certain features are exhibited by the model that are actually present in the system may not be reflected in the matrix because of improper classification. The classification and aggregation problems are indeed all-permeating in systems of interdependent parts.

Various quantitative indexes have been proposed for measuring such features as the degree of "division of labor," the degree of "economic interdependence" in the economic system.[11] Many concepts of an elusive and loosely defined nature that were developed early in the history of economics are finding precise quantitative specifications. This is a definite sign of the fact that economics is already on a cumulative growth path similar to that followed by natural and physical sciences.

3. Feasibility of a Given "Bill of Goods"

Let l_j, k_j, and q_j designate the requirements of labor, capital, and land per unit of output of sector j. Then the "resource-requirements matrix" for the economy is given by:

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[11] See, for example, Chenery and Clark, Chapters IX and X; C Yan and Edward Ames, "Economic Interrelatedness," Review of Economic Studies, October, 1965.

(7.17)
$$R = \begin{bmatrix} l_1 & l_2 & \cdots & l_n \\ k_1 & k_2 & \cdots & k_n \\ q_1 & q_2 & \cdots & q_n \end{bmatrix}$$

Recalling that the j-th column of $[A_{ij}]$, the inverse matrix, gives the output of each industry necessary for a unit increase in the final demand for the j-th industry, the following quantity is of interest:

(7.18)
$$\sum_{i=1}^{n} l_i A_{ij}$$

Equation (7.18) gives the total labor requirements by the economy as a whole if the final demand for the j-th sector increases by one unit. Similarly, $\sum_{i=1}^{n} k_i A_{ij}$ and $\sum_{i=1}^{n} q_i A_{ij}$ give the corresponding capital and land requirements, respectively. These relations can be summarized by means of matrix notation:

$$Rx[A_{ij}] = \begin{bmatrix} l_1 & l_2 & \cdots & l_n \\ k_1 & k_2 & \cdots & k_n \\ q_1 & q_2 & \cdots & q_n \end{bmatrix} \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & & \vdots \\ A_{n1} & A_{n2} & \cdots & A_{nn} \end{bmatrix}$$

(7.19)
$$= \begin{bmatrix} \Sigma l_i A_{i1} & \Sigma l_i A_{i2} & \cdots & \Sigma l_i A_{in} \\ \Sigma k_i A_{i1} & \Sigma k_i A_{i2} & \cdots & \Sigma k_i A_{in} \\ \Sigma q_i A_{i1} & \Sigma q_i A_{i2} & \cdots & \Sigma q_i A_{in} \end{bmatrix}$$

where the sums are taken over $i = 1, 2, \ldots, n$. Now let $F = [f_{ij}]$ represent matrix (7.19). The j-th column of this matrix shows the requirements of various resources per unit of output of industry j.

The F matrix may be used to compute the resource requirements that correspond to a given "bill of goods" (or program of final demand).

$$(7.20) \qquad \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ f_{31} & f_{32} & \cdots & f_{3n} \end{bmatrix} \begin{bmatrix} D_1 \\ D_2 \\ \vdots \\ D_n \end{bmatrix} = \begin{bmatrix} \Sigma f_{1j} D_j \\ \Sigma f_{2j} D_j \\ \Sigma f_{3j} D_j \end{bmatrix}$$

The vector on the right-hand side of (7.20) gives the requirements of labor, capital, and land for indexes 1, 2, and 3, respectively. This vector may be compared with the vector of supply of resources:

$$(7.21) \qquad \begin{bmatrix} L \\ K \\ Q \end{bmatrix} \gtreqless \begin{bmatrix} \Sigma f_{1j} D_j \\ \Sigma f_{2j} D_j \\ \Sigma f_{3j} D_j \end{bmatrix}$$

where L, K, and Q designate the available supplies of labor, capital, and land, respectively. If < holds in (7.21), the given "bill of goods" is not "feasible."

The F matrix may also be applied in computing a set of final goods and services whose production would assure full employment of resources.[12]

The above analysis is most useful when it is carried out on the basis of a more disaggregated resource matrix with, say, m rows rather than just three. The classification of resources into three broad categories of labor, capital, and land was adopted merely for illustrative purposes. No inherent characteristic exists which would make this classification better or worse than another. The logic of the analysis remains the same regardless of the number of different resources distinguished within the general category of "resource." The specific classification adopted depends on the purpose of the analysis. A discussion of the so-called Leontief paradox will illustrate this point.

4. The Leontief Paradox

It is commonly believed in international economics that a country tends to export commodities that need relatively more of the resource which is relatively abundant. Thus the United States is said to be a capital-abundant and labor-scarce economy. It is expected, therefore, that the United States export capital-intensive and import

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[12] See Yan, pp. 77-81.

labor-intensive goods. It was very striking when Leontief announced that his findings show that the actual pattern of the United States international trade is directly opposite to the view commonly held. That is, in actuality the United States exports labor-intensive and imports capital-intensive goods.[13]

Let $[E_1, E_2, \ldots, E_n]$ designate column vector of the set of exported items in the American economy and let $[M_1, M_2, \ldots, M_n]$ stand for the set of imports. Then, applying the first two rows of the F matrix above, the following 2-component vector is defined:

$$\begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_n \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{n} f_{1j}E_j \\ \sum_{j=1}^{n} f_{2j}E_j \end{bmatrix} \tag{7.22}$$

Here $\sum_{j=1}^{n} f_{1j}E_j$ measures the total amount of labor and $\sum_{j=1}^{n} f_{2j}E_j$ measures the total amount of capital "congealed" in the given set of exports.

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[13] W. W. Leontief, "Domestic Production and Foreign Trade: the American Capital Position Re-examined," Proceedings of the American Philosophical Society, XCVII, No. 4, September, 1953; for a simplified discussion see Yan, pp. 81-85; for a summary of views of the followers and critics of Leontief on this issue see, John S. Chipman, "A Survey of the Theory of International Trade: Part 3, The Modern Theory," Econometrica, pp. 44-57. An extensive bibliography on the subject is presented here.

Similarly for imports:

$$
(7.23) \qquad \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{n} \\ f_{21} & f_{22} & \cdots & f_{n} \end{bmatrix} \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_n \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{n} f_{1j} M_j \\ \sum_{j=1}^{n} f_{2j} M_j \end{bmatrix}
$$

The objection often raised against this analysis is that in (7.23) Leontief applies the domestic resource-requirement coefficients, f_{ij}, to measure the amount of resources "congealed" in the imports which are produced outside of the United States and are, therefore, subject to a different set of coefficients. However, it can be said that the technology matrix of its major trade partners are sufficiently similar to that of the United States to justify the above analysis.

The actual statistical findings of Lenotief were as follows:

$$
(7.24) \qquad \Sigma\, f_{ij} E_j > \Sigma\, f_{1j} M_j
$$

$$
(7.25) \qquad \Sigma\, f_{2j} E_j < \Sigma\, f_{2j} M_j
$$

The inequality (7.24) states that the labor that went into the exports of the United States during the period of analysis[14] exceed the labor that would be necessary if the country actually produced its otherwise imported materials. The inequality (7.25) states that the

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[14] The actual period of analysis chosen by Leontief was the year 1947.

amount of capital that went into the production of the export items was less than that which would have been required if the actually imported materials were to be produced domestically. Thus the labor/capital ratio was higher for exports than for imports:

$$\frac{\Sigma f_{1j} E_j}{\Sigma f_{2j} E_j} > \frac{\Sigma f_{1j} M_j}{\Sigma f_{2j} M_j} \tag{7.26}$$

where the sums are taken over $j = 1, 2, \ldots, n$. The inequality (7.26) states that the export goods were labor-intensive relative to the imported goods during the period under analysis.

5. Summary and Conclusion

In this chapter four distinct types of analysis were presented in order to illustrate the qualitative improvement in analytic economics due to the formulation of disaggregated models. These were: multiplier analysis, structural analysis, feasibility analysis, and the Leontief paradox.

It was seen that whereas the general logic of the multiplier analysis was the same in the Keynesian and the Leontief models, the latter provides not one overall multiplier for the economy--as is the case with the former--but a set of multipliers, one for each sector within the economy. The significance of this improvement in relation to an operative economic policy cannot be overestimated.

In the case of structural analysis, the credit must go entirely to the disaggregated model. The Keynesian model works with an aggregative production function--it is a one-industry model.[15] As such, it deliberately overlooks the pattern of interrelationships among industries. It abstracts from this aspect of the economic phenomena. Thus the concept of structural analysis is irrelevant in a Keynesian context.

This indicates that the less aggregative model can be used for the analysis of some phenomena which are left out in the more aggregative models. Therefore, the problem of aggregation is not merely one of degree. It is primarily a qualitative one. Certain new features are introduced as a result of disaggregation. The nature of the analysis often changes.

What is said of the structural analysis can be repeated exactly for the allocation problem and the Leontief paradox.

The foregoing comments should not be interpreted as a cricitism of the Keynesian system. An analytical system, like any other human creation, can be evaluated only in relation to the purpose it aims to achieve and in the context of the historical setting in which it has evolved. Some considerations in this regard will be pursued in a chapter dealing with the methodological aspect of aggregation.

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[15]See Chapter V.

PART III

CHAPTER VIII

DISAGGREGATION WITHIN A MONETARY MODEL

In the preceding chapters it has been suggested that disaggregation as a general strategy of theory formulation in economics is one important way in which the discipline can make progress along empirical lines. In this chapter this general strategy is applied to a simple theory concerning the velocity of circulation of money. As far as this author has been able to determine this sort of disaggregative monetary model has not been proposed anywhere in the literature.

1. General Remarks

Consider the following tautology:

$$Y \equiv M\,V$$

where Y is some specific measure of total expenditures, M the total stock of money, and $V = \frac{Y}{M}$ is <u>defined</u> as the velocity of money.

Generally Y is specified as the gross national product and M as the sum total of demand deposits and currency and coins existing in the economy. However, alternative definitions of Y and M are also possible.

In fact references to the transaction velocity of money are found quite frequently in the literature. Here no distinction is made between financial and non-financial assets, or transactions related to the final and intermediate goods. Thus, if T measures the total receipts of economic agencies during a year and if M is the average level of money stocks during the period, then $V = \frac{T}{M}$ measures the transaction velocity of money.

A third type of velocity may be defined in relation to the gross output (in the Leontief's sense) of the economy.[1] Here Y is specified in the following way:

$$Y = \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij} + \sum_{i=1}^{n} D_i$$

where x_{ij} are the intersectoral deliveries and D_i is the output of final goods and services by sector i.

Given a definition for M it is true that the GNP velocity of money is the lowest and the transaction velocity the highest of the three.

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[1]The author has not seen any reference to this type of velocity in the literature. This may be explained by the fact that the intermediate products did not interest the Keynesian economists who are used to think in terms of value-added categories. Also the fact that national income statistics provided only the value-added figures in the published form may be another explanation.

Two questions are of interest with regard to V:

(a) The empirical meaning of it; and

(b) The status of V as a parameter in certain theoretical schemes.

These questions will be examined in the light of some of the methodological principles developed in the earlier chapters.

2. On Empirical Meaning of Velocity of Money

It should be noted that V is automatically defined as a magnitude once Y and M in the identity $Y \equiv M V$ are defined. Thus in a formal sense no more than this is required. If V, as defined in this formal way, happens to be a useful intellectual stepping stone, then it is used freely without necessarily bothering with the actual empirical process that corresponds to it, providing that there exists one at all. It is in this formal sense that V is usually used in the literature.[2]

V in this formal sense may or may not correspond to the true empirical V. Given a definition for M then there must exist a unique

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[2]See, for example, Friedman, Milton, and David Meiselman, "The Relative Stability of Monetary Velocity and the Investment Multiplier in the United States, 1897-1958," Commission on Money and Credit, Stabilization Policies , New York: Prentice Hall, 1963; Meyer, T., "Multiplier and Velocity Analysis: An Evaluation," Journal of Political Economy, December, 1964; and Ando, Albert, and Franco Modigliani, "Velocity and the Investment Multiplier," The American Economic Review, September, 1965.

empirical V. In this sense V may be thought of as a measure of the intensity of use of the existing stock of money. This empirical V is most closely approximated by the transaction velocity of money discussed above. The two other aforementioned interpretations of V are not the "true" velocities in the empirical sense, for there can be no more than one empirical velocity. These are, so to speak, residual velocities in the sense that they involve the suppression of one or more classes of transactions. They imply that the overall velocity of money can conceptually be separated into velocities with respect to various domains of transactions, such as financial transactions, transactions with respect to final goods and services, etc.

It is to be noted that all the statistical conventions that are involved in the definition of GNP are necessarily involved in the definition of V when it is used with reference to GNP. For example, several components of GNP are fully or partially imputed values which involve no actual transactions, and therefore no use of money. The existence of imputed values in GNP tends to give a higher estimate of V than one would otherwise obtain. If the imputed portion of GNP were a fairly stable percent of the whole, the above problem would not be of any consequence for many purposes, because it is generally changes in V rather its level that is of interest in analysis. But the imputed portion of GNP is likely to change over time because of structural changes within the economy and also because of redefinitions introduced in the statistical series. Of course if the imputed values constitute a relatively small proportion of the GNP then their variation due to structural change and/or statistical redefinition will not affect V significantly. Nevertheless the point should not be ignored, because if a disaggregated approach is taken for looking at "sectoral velocities" along the lines suggested later in this chapter, then the aforementioned variations in the imputed values in GNP may significantly affect the relative sectoral velocities. Thus a definition of GNP net of imputed values is more relevant in the calculation of V than the figures in the original form.

Fortunately the problem of imputation and changes in the definition of money is much less severe than that in relation to GNP. In the case of the former once it is decided to use, for example, demand deposit plus currency and coins plus a weighted average of several types of "near-monies" as a definition of money, then reasonably accurate time series can be obtained for such a measure with, relatively speaking, little effort.

The fact that the velocity of money is defined with reference to different measures of total expenditure in the economy indicates that it is not the true empirical velocity of money--the actual number of times that a typical dollar is used for payment--which interests economists, but a strategically defined concept of V. In other words the tautology Y = M V is at the very outset pregnated with some degree of theorizing: The elements Y and M are essentially theoretical notions in the sense that one must first resolve the theoretical question of precisely what constitutes money or income. But the degree of theorizing around this tautology has not, as is well known, stopped at this point.

3. Theorizing around the Concept of Velocity of Money

As discussed in section 4 of Chapter III, all theorizing involves assumptions of invariance, suggesting that one or more aspect of reality remains constant or changes predictably. The invariant core of input-output analysis is the technology matrix. That of the simple Keynesian scheme is the stability of the consumption function expressed in the alleged constancy of the multiplier. The notion of invariance in monetary theory is expressed in the alleged constancy (or predictability) of the velocity of money. By assuming V invariant, the relation between Y, M, and V is no more purely tautological; it assumes a theoretical character, the hypothesis proposed being the alleged invariance of V. In fact this hypothesis constitutes the very core of the monetary theory.

The hypothesis of ivariance of V has always been formulated and tested in a highly aggregative form. Such aggregative formulation in the area of monetary theory is well in line with the prevailing mode of economic analysis in general. This methodological tendency has been studied from several angles in the preceding chapters. It was concluded that disaggregative formulation as a strategy of theory building is often an unavoidable step if economics is to make progress as an empirical science.[3] It is, therefore, desirable to investigate the consequences of disaggregation within the theory expressed by

$$Y = M V$$

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[3]To this date many controversies around the propositions of monetary theory remain unresolved. The bibliography on these controversies are too extensive to be presented here. The September, 1965 issue of AER mentioned in the preceding footnote reflected much of the central issues involved. Participants were Ando, Modigliani, De Prano, Mayer, Friedman, and Meiselman. Here are some of the most recent works: Cagan, P. and A. Gandolfi, "Monetary Theory, the Lag in Monetary Policy as Implied by the Time Pattern of Monetary Effects on Interest Rates," American Economic Review, May, 1969; Friedman, M., "The Role of Monetary Policy," American Economic Review, March, 1968; also see ibid., May, 1969.

Because inspite of such intensive participation of many economists there seems to be little progress towards resolving the controversies, a reformulation of the theory is justified. The theory in its present form can not be rigorously tested because of several reasons. The most important problem seems to be the lack of precise definition for M and Y. Various empirical studies utilize different definition for M. The result is that the theory can be neither accepted nor refuted. One definition of money gives favorable results for one period but not for other periods. Another definition of money gives opposite results. In essence there is no one theory but many theories. There are as many different theories as there are definitions accepted by various people who test the theory empirically.

As it will be observed, no final judgment can be passed on the advantage of such a disaggregation on a priori grounds. Yet the formal setup of a disaggregated theory is a first step towards its empirical testing. The actual testing of the theory constitutes a project in itself. Only the theoretical aspects of such a model will be examined here.

4. A Disaggregated Monetary Model

It was seen in the preceding sections that Y in the tautology $Y = M V$ can be defined in different ways. In the following analysis Y will be used as defined below

$$Y = \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij} + \sum_{i=1}^{n} D_i \tag{8.1}$$

where x_{ij} and D_i represent the same magnitudes as defined previously in this chapter.

There are several reasons for chosing this measure of Y rather than the more conventional one, namely, GNP. First, this measure explicitly defines the variable in detail. It is always desirable for the theory to define its variables, thereby restricting the degree of arbitrariness in the stage of empirical verification. Even if this goal cannot be fully adhered to in all circumstances, it is an objective worth working for to the extent possible in any specific setting.

Second, the disaggregation in the model is introduced along the lines of industrial classification, since measures of gross output by industrial sectors have already been made available for several years since 1939 by the input-output studies, and it is advisable to formulate the theory in such a way that would make maximum use of existing information. If a GNP measure of Y were chosen one would have to obtain a lot of unpublished data from the Department of Commerce in order to break down the GNP on the basis of industrial classes. In fact it is very likely that all of the necessary information is not available even in the unpublished documents of the Department of Commerce.

Third, the difference between the two definitions is essentially the intersectoral flows and the use of money for such transactions. That is, the component $\sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij}$ of the total expenditure is the basic difference in the two measures. Such intersectoral transactions involve actual flows of goods and services; indeed they are merely the financial counterparts of such "real" flows. They are not like purely financial transaction whose volume can change substantially without significantly and directly affecting the magnitude of many economic variables. Since the central issue is that of stability of V, the inclusion of the intersectoral transactions which are no less stable than the GNP transactions should not cause V to be any more or less stable than the case where the intersectoral transactions are left out.

Fourth, the imputed portions of GNP are separated into a few sectors, thus giving relatively more "pure" data for the rest of the sectors which do not have an imputed components in their measure of output. As a matter of fact as a strategy of empirical testing of the multisectoral model presented later in this chapter, one may proceed in stages, testing the hypothesis for the sectors whose total transactions most fully involve money as defined in the model, and then at a later stage devise methods of estimating the degree of variation in the sectoral velocities due to the existence of transactions that do not involve the use of money.

The above points have probably given some impression as to the type of theory that is to be presented. Now the theory can be stated in its simplest form as follows:

Let the economy consist of n sectors, sectors being (defined in the Leontief's sense,) identified by the type of product they produce. Then at any moment of time the total stock of money M in the economy is distributed in a specific manner among the various sectors. Therefore one can speak of an average stock of money for each sector. Let M_i designate the average stock of money in sector i. Then the following tautologies may be written:

$$Y_i = M_i V_i \qquad (i = 1, 2, \ldots, n) \tag{8.2}$$

where V_i is defined as the velocity of money in sector i and Y_i is the gross output of sector i inclusive of intermediate product deliveries, i.e.,

$$(8.3) \qquad Y_i = \sum_{j=1}^{n} x_{ij} + D_i \qquad (i = 1, 2, \ldots, n)$$

The theory consists of the proposition that the tautologies (8.2) can be written as a system of equations in which $V_i (i = 1, 2, \ldots, n)$ are the parameters and Y_i and $M_i (i = 1, 2, \ldots, n)$ constitute the endogenous variables. To say that V_i is a parameter is to say that it must be specifiable statistically on the basis of past data, or current cross-section studies, assuming that such a technique can be meaningfully applied in this context, or by some other method.

In order to make the theory complete and ready for verification (or refutation) through confrontation with data it is necessary to define the variables. Y_i has been defined above. M_i is defined in two alternative ways:

(1) currency and coins plus demand deposits; and

(2) currency and coins plus demand deposits plus a weighted average of several classes or near monies.

In the second case the question of how far one should proceed along the liquidity scale and what weights should be assigned to each type of near money deserves to be studied separately and in great details. Thus only the first alternative is ready to be used in the empirical testing of the theory. The second needs further elaboration and specification. It should be treated not as a new theory but rather as a suggestion for the direction of further investigation. Such an investigation shall not be pursued here.

Taking the first definition of money, the theory is complete: Its parameters and variables are distinguished and the variables are defined.

It may be instructive to contrast this theory with the aggregative theory expressed by

$$Y = M\,V \tag{8.4}$$

In (8.4) Y will be interpreted as gross output of the economy in the manner specified in (8.1). This, as already observed, is not likely to affect the stability of V and does not, therefore, change the fundamental proposition of the monetary theory regarding velocity of money.

Aggregating the sectoral relations $Y_i = M_i\,V_i$ results in

$$\sum_{i=1}^{n} Y_i = \sum_{i=1}^{n} M_i\,V_i \tag{8.5}$$

(8.6) or
$$\sum_{i=1}^{n} Y_i = Y = \sum_{i=1}^{n} M_i\,V_i$$

Since $Y = M\,V$, it follows that

$$M\,V = \sum_{i=1}^{n} M_i\,V_i \tag{8.7}$$

(8.8) where
$$M = \sum_{i=1}^{n} M_i$$

by definition. It follows from (8.7) that

$$V = \frac{1}{M} \sum_{i=1}^{n} M_i V_i \tag{8.9}$$

which, in the "open form," reads as

$$V = \frac{M_1}{M} V_1 + \frac{M_2}{M} V_2 + \ldots + \frac{M_n}{M} V_n \tag{8.10}$$

Equation (8.10) states that the velocity of money in the economy as a whole is a weighted average of the sectoral velocities, the weights being the relative average stock of money in each sector.

In order to evaluate the significance of this theory assume that V_i are stable. Some of the consequences of this assumption are studied in the next section.

5. Significance of the Disaggregative Monetary Model

Observe that with constant V_i $(i = 1, 2, \ldots, n)$ in (8.10) V is a function of $(n-1)$ relative stocks of money in the various sectors. There are only $(n-1)$ independent ratios because

$$M_j = M - \sum_{i \neq j}^{n} M_j \qquad (j = 1, 2. \ldots, n) \tag{8.11}$$

Thus V is a mapping from $(n-1)$-space into 1-space. In general V takes different values as $\frac{M_1}{M}$ change. In specific terms, as money flows from one sector of the economy into another sector, hence changing the existing pattern of relative sectoral money stocks, the overall velocity of circulation of money in the economy changes, even though the sectoral velocities are assumed constant. For example, if the stocks of money in one or more relatively high-velocity sectors increase at the expense of one or more relatively low-velocity sectors, then the overall velocity of money will increase. Therefore, assuming the empirical constancy of V_i, one possible explanation for the observed variability of the velocity of money in the economy as a whole is the change in the relative stocks of money that the various sectors hold.

In this way the theory could lead to what may be termed a structural approach to monetary policy. This type of policy would induce at times of recession a flow of monetary stocks from relatively low velocity to relatively high velocity sectors, thereby pushing V, and with it $Y = M V$, upward, getting an output and employment effect provided that the existing idle resources are willing to be employed at the existing rate of reward. One way to induce such a predesigned intersectoral flow of funds would be to manipulate the interest rate sectorally.

Such a policy would of course be controversial because it involves helping some sectors at the expense of other sectors, resulting in a net gain for the society as a whole, while hurting some sectors, at least in the short run.

In the long-run the multiplier effect will take over and the increase in output and employment will spread throughout the economy. The disaggregative multiplier analysis of Chapter VII showed specifically how this process can occur.

The disaggregative formulation presented above helps clarify one point about the monetary policy: not only the amount but also the distribution of an increase in the supply of money is to be considered in a rational monetary policy. It may be argued that money will sooner or later go where it should go and that the channels through which a given increase in the money supply is introduced are of no essential consequence. This view of things ignores the fact that time is always at the very center of economic calculations and that any reduction in the lag between a policy act and its effect is of extraordinary value in the applicability of policy aimed at avoiding unnecessary economic instability. In an uncertain world reducing the duration between two related events amounts to reducing the degree of uncertainty in the relationship involved. Such possible reductions is uncertainty would immensely help the progress in applied economics.

In an inflationary economy, along with other measures, it may be decided to change the relative stocks of money in various sectors in favor of relatively low velocity sectors. Suppose that as an alternative policy the stocks of money in the economy as a whole are made to go down. Regardless of the long-run effect, the impact of the former policy would be more immediate provided that in addition to changing the relative stocks in each sector the level of money stocks in the economy as a whole is reduced.

This type of structural approach to monetary policy has its counterpart in fiscal policy. At least as far as the expenditures side of the fiscal policy is concerned, it is necessarily selective, though its selectivity often lacks a formal analytical framework and is not always guided by the goals of stabilization, full employment, and other macroeconomic objectives. Often political considerations overcome the economic ones.

Likewise in the area of monetary policy the monetary authorities have access to selective credit control instruments. But again this selectivity lacks a theoretical foundation and is often guided by ad hoc measures. The significance of the above disaggregative model is that, in addition to points mentioned earlier, it takes a step towards developing a theoretical foundation for a structural approach to monetary policy. Further, it opens up a new theoretical avenue leading to all sorts of interesting hypotheses. This line of thought shall not be pursued further here. Instead some directions for widening the scope of the theory will be examined.

6. Widening the Scope of the Theory

Any theory is of necessity concerned with explaining some aspects of reality while treating other aspects of reality as given. The explanatory scope of a theory may be widened but it can never be so wide as exhausting the whole of reality in its infinite-dimensional complexity. One possible systematic method of widening the scope of a theory is to "explain" one or more of its parameters in terms of newly introduced independent variables and parameters, thereby converting the original parameters into new relations embedded in the theory.

For example suppose the following hypothesis is advances for explaining V_i :

$$V_i = \alpha_i S_i + \beta_i d_i + \gamma_i \qquad (i = 1, 2, \ldots, n) \tag{8.12}$$

where V_i designates velocity of money, S_i total sales of goods i during the period, and d_i an index of durability of goods i.[4] α_i, β_i, and γ_i are the parameters of the theory, reflecting the degree of influence of S_i, d_i, and "all other" factors on V_i, respectively.

Equation (8.12) states that the velocity of circulation of

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[4]Whether such a hypothesis makes any sense is not the issue at this point. This question will be examined later.

money in sector i depends on the level of stocks of goods i, the durability of such goods, and a set of other factors not specified. Further the relationship between V_i, S_i, and d_i are linear and additive.

Now realtion (8.12) may be substituted for V_i in $Y_i = M_i V_i$ referred to above:

$$Y_i = M_i (\alpha_i S_i + \beta_i d_i + \gamma_i), \qquad (i = 1, 2, \ldots, n) \tag{8.13}$$

This is essentially the same theory as $Y_i = M_i V_i$ except that it has an "explanation" for possible variations in V_i.

Now turning to the plausibility of the hypothesis (8.12), the author believes that the durability of goods is probably an important determinant of the velocity of money in a sector. For example the velocity of money in grocery stores as measured by the ratio of total sales to their average monetary balances is probably much lower than that of, say, construction firms. But there is, of course, no way to establish this proposition *a priori*. As for the other variables, namely, the sales volume of each sector, it may be argued that at higher levels of sales the firms in the sector tend to hold less idle balances, activating their money in the form of addition to inventory, or expenditure on preparing the stand-by producing capacity for use in meeting new peaks in sales. There is little justification to more elaboration on these points prior to the actual empirical testing of the theory.

It is convenient to summarize the statement of the theory before examining its meaning in more specific terms. Let S_i measure the gross sales (in the Leontief's sense) of sector i. Then $Y_i = S_i$ and (8.13) would read as follows:

$$(8.14) \qquad Y_i = M_i\,(\alpha_i\, Y_i + \beta_i\, d_i + \gamma_i), \qquad (i = 1, 2, \ldots, n)$$

which may be rewritten as

$$(8.15) \qquad Y_i = \frac{M_i(\beta_i\, d_i + \gamma_i)}{1 - \alpha_i\, M_i}, \qquad (i = 1, 2, \ldots, n)$$

Assume that $\alpha_i, \beta_i > 0$. Then the partial derivatives and their signs are as follows:

$$\frac{\partial Y_i}{\partial M_i} = \frac{(\beta_i\, d_i + \gamma_i)\,(1 - \alpha_i\, M_i) + \alpha_i\, M_i\,(\beta_i\, d_i + \gamma_i)}{(1 - \alpha_i\, M_i)^2}$$

$$(8.16) \qquad = \frac{(\beta_i\, d_i + \gamma_i)}{(1 - \alpha_i\, M_i)^2} > 0$$

and

$$(8.17) \qquad \frac{\partial Y_i}{\partial d_i} = \frac{M_i\, d_i\,(1 - \alpha_i\, M_i)}{(1 - \alpha_i\, M_i)^2} < 0$$

since $\alpha_i M_i$ may plausibly be assumed positive.

Equation (8.16) states that as the stock of money in sector i changes the output of the sector tends to change in the same direction. Equation (8.17) states that for a given stock of money the higher the durability of goods the lower the level of output in that sector. Since durability of goods within a sector are not subject to manipulation, this variable is not a very interesting variable. Thus it may be replaced by some other variable such as the rate of interest. The formal technique just described is exactly repeatable with regard to a new set of explanatory variables. After the first "simple theory" regarding the invariance of V_i is empirically tested, then the explanatory scope of the theory may be expanded along lines similar to those outlined above with perhaps half a dozen explanatory variables introduced. With the above formal analytical framework available, it is very easy to get carried away with purely theoretical reasoning based on "plausible assumptions" and regarding this as valuable in itself. However, the proper approach is the systematic empirical testings of the various theories. Only in this way can objective knowledge about reality be obtained. Pure theory, no matter how plausible its assumptions, remains a subjective construct until such time as it is verified through direct or indirect confrontation with facts.

7. Some Problems Regarding the Empirical Testing of the Theory

Only the "simple" multisectoral monetary model presented above is examined in this section. This theory states that V_i in $Y_i = M_i V_i$ are invariant.

Two aspects of the problem of empirical testing of the above theory are of interest. First, the question of operational definition of the variables. Second, the availability of the data. The first question was discussed in section 4. It may be added that the particular classification of industries and its degree of fineness may be crucial to the test. Since the theory involves a "look-and-see" type of hypothesis it may be advisable to test it for several degrees of aggregation in the classification of data. It may be the case that a classification of data on other bases than the industrial sectors leads to more favorable results. But this would amount to the formulation of a new theory. Thus classification and aggregation are important aspects of the empirical testing of the theory. The principles underlying the classification used and the degree of fineness of this classification (or aggregation within the model) can play a determining role in the verification of the theory.

The second important question related to the empirical testing of the theory is that of the availability of data. It has already been pointed out that one of the reasons for proceeding to disaggregate along the input-output lines of classification was that this would enable the theory to make use of the already existing disaggregative data of sectoral gross outputs. As for the data in relation to M_i, those portions of a sector's average monetary stocks that are related to the activities of the firms in that sector can be obtained at a reasonable cost. The figures for consumers' transactions in each sector will probably have to be estimated to the testing of the theory. It is convenient that, as a research effort, it can proceed in separate steps. A pilot program involving no more than half a dozen sectors may be used in order to see whether the hypothesis is worth bothering with. In case favorable results are obtained then a number of sectors are examined, the degree of exhaustiveness of the study being limited only by the availability of research funds.

CHAPTER IX

SUMMARY AND CONCLUSIONS

This study may be described as containing the distinct but interrelated parts. Chapters I, II, and III, constituting Part I, deal with methodology in economics. Chapters IV, V, VI, and VII comprise Part II, which deals with analysis in economics against the background of the material introduced in Part I. Part III consists of Chapter VIII which provides an instance of applying the methodological and analytical principles developed in Parts I and II in a particular field of ecomics, namely, monetary theory.

Part I attempts to (1) provide a synoptic view of the _generic features_ of the method of empirical sciences (Chapter II) in order to (2) evaluate economics as an _empirical_ science (Chapter III) by means of comparing the methodological characteristics of economics with those of other empirical sciences. The assumption underlying the analysis in this part is that, although each empirical science posses-ses a set of _specific_ approaches to the understanding of objective phenomena, this set of approaches is characterized by certain _generic_ features which are present in other sets of approaches specific to other empirical sciences. That is, at an appropriate level of abstraction, it is possible to compare certain aspects of the methodology of empirical sciences. Such a level of abstraction would necessarily suppress the particularities of these sciences in order to focus on their common elements. This leads to epistomological considerations.

Epistomology, or theory of knowledge, deals, among other things, with the interdependence between fact and theory in relation to scientific work. The philosophical crystallization of this interdependence is manifested in the interplay of two opposing tendencies among philosophers and scientists: objectivism versus subjectivism. That is why it was necessary to embed the problem into a philosophical framework in Chapter II. However, in order to keep the discussion fairly concrete, two different empirical sciences were selected to serve as specific instances of the process of generation of scientific knowledge. These are biology and psychology. References are frequently made to other sciences such as chemistry and physics as well.

Classification in biology was studied in its historical development. It was found that, development in theoretical biology and in particular, the rise of evolutionary theories of Darwin and his followers could not have taken place without a certain degree of progress on the empirical front. The classificatory schemes of Linnaeus were a precondition for the rise of evolutionism, although the latter provided a more consistent and universal basis for taxonomic work in biology than that provided by the former. Linnaeus's insistence on the constancy and objectivity of species helped to tie biology, so to speak, "close to ground," give it a profoundly inclusive factual base. The precise way in which this factual taxonomic work helped biology to make progress is explored in Chapter II. Progress in biology exemplifies the triumph of objectivism over subjectivism in science.

In psychology the influence of Freud has given impetus to subjectivistic tendencied, leading to "analysis"based on arbitrary assumptions and preconceptions. Taxonomic works in this field have as yet produce little practically useful results. One of the objectivistic tendencies in psychology is the Pavlovian approach which attempts to relate behavior to the physiology of the higher nervous system, the cerebral cortex. Fundamental in this relationship is the theory of conditioned (and unconditioned) reflexes. The method of the Pavlovian school is observational and experimental. The objectivity of this method stands in sharp contrast to the subjectivity of the Freudian school. The former is characterized by accumulative process of growth similar to that of other empirical sciences. Not so with the latter.

The perpetual interplay between facts and theories that is characteristic of empirical sciences can be schematically described in terms of three interdependent investigative processes, namely, induction, deduction, and reduction. Classification is essential in all three of these processes. In induction facts are "ordered" with regard to one or more characteristic. In deduction logical operations are applied to "categories." Categories are actually "empty boxes" to be filled by appropriate data when the given theory is to be empirically tested. Thus in deduction theoretical classification occurs. In reduction theories are confronted with facts. Here the problem of establishing correspondence rules between theoretical categories and classes of data arises. If such correspondence is not attainable, then either theoretical, or empirical, or both classificatory schemes are to be revised. The interrelations between these various aspects of the scientific method is synoptically reviewed at the end of Chapter II. It is concluded that all empirical sciences need a method which hinges on the perpetual interaction between theoretical formulation and empirical data. Without this a given science may develop into a position where its theories are self standing logical constructs, not refutable because they cannot be tested, and not useful because they have severed ties with the empirical phenomena they originally set out to explain.

Chapter III shows that economics seems to have fallen into such a path. Though many remarkable advances have been made in the science, the popularized methods of building an "ideal" model, the subjectivist tendencies that try to reduce the science to a branch of praxiology, and reflections of these fundamental methodological approaches at the level of analysis of specific economic problems, all these have had a significant role in preventing the discipline from making a more rapid cumulative progress.

One manifestation of the separation of theoretical and empirical works in economics is the tendency of the theoretician to formulate theories in terms of few aggregative variables. These aggregates are often themselves theoretical entities and their specification needs separate theories. No theory is specified until its variables and parameters are well specified. The aggregative models often fail to conform to this standard, with the consequence that the theory at best remains vague and open to many interpretations, thus constituting not a theory but a class of theories, and at worst it is simply useless.

A second manifestation of the aforementioned phenomenon is the rise and dominance of partial equilibrium method--an approach which is inherently not conducive to empirical investigation except in limited cases.

The notion of invariance is introduced in Chapter III. It is observed that invariance constitutes the generic feature of all types of "order" in nature. Scientific theories can have empirical relevance only if they involve invariant elements. The Walrasian general equilibrium system cannot be implemented empirically not, as is often observed, because the number of equations to be solved is too large, but because it fccuses on, generally speaking, the highly volatile (and therefore not observable) relations of supply and demand. By way of contrast, the linear programming, the von Neumann, and the Leontief models are all empirically significant theoretical constructs because the central concept of these models, namely, "activity" is a well defined and observable entity. Further the substantial inertia of the technological process is a basis for building an empirical analogue for the "structure" of the economy, Leontief has succeeded in making a start in this direction.

All three of the models just mentioned are characterized by disaggregative formulations in which the categories (the variables) are not theoretical entities which need further specification and separate theories but ones which are completely defined within the model. Thus arbitrariness is done away with to a great extent. Further, the disaggregative formulation allows the model to have room for the differences that are economically significant and are actually observed. In general, the larger the number of independent variables in a model the greater the ease with which the model can be made to replicate the economic reality. Of course it is not only the number of variables but also the nature of relationships hypothesized by the model that determines how closely it describes real phenomena. Disaggregative formulation is an explicit recognition of the empirical differentiation that is observed in the economic system. The more aggregative the model the more distant its categories from immediately observed phenomena.

Part II has two distinct objectives. One is to bring together within a uniform framework ideas--scattered in the literature--in relation to various aspects of the classification and aggregation problem within the Leontief static model. The second objective is to give analytical substance to the methodological issues raised in Part I.

Chapter VI deals with the first objective. It studies the problem of classification and aggregation at first in a purely formal way and then empirically, in relation to the natural and technological conditions of production. Some problems of statistical implementation of input-output tables are also studied here.

The second objective is coped with in Chapters IV, V, and VII.

Chapter IV concentrates on social accounting aspects of two theoretical models, namely, the Keynesian and the input-output models. The fundamental identities of each are introduced. The two accounting framework are embedded into a more inclusive frame which generates the former two as its special cases. This provides a basis for comparing the two theories in Chapter V.

Chapter V provides a sketch of the "complete Keynesian" model and also of the theory of input-output analysis. Particular attention is given to the treatment of the production function in the two models. The Keynesian model aggregates all the production sectors of the economy into one. Not so with the Leontief model. The latter possesses an n-sector production function. The Leontief production function is contrasted with the Cobb-Douglas function, the latter representing one of the most popular mathematical specifications of the Keynesian production function. It is shown that constancy of production coefficients which is based on the assumption of technical nonsubstitutability of inputs in the Leontief model, is the result of optimizing behavior of entrepreneurs in the case of the Cobb-Douglas function. But this similarity in one result of the two types of functions should not overshadow their fundamental differences. The Leontief production function amounts to no less than a direct denial of the neoclassical marginal productivity theory.

In Chapter VI it is shown that many instances of apparent factor substitution are indeed fully consistent with the assumption of constant coefficients of production and nonsubstitutability of factors! This is the case because of the aggregative nature of the categories that serve as elementary concepts in such observations of alleged factor substitution. Thus, the aggregative approach to some economic phenomena may lead to such observations that are contrary to the true empirical process that occurs.

Chapter VII deals with the analytical significance of the disaggregative approach in theory formulation. It is shown that many concepts that are vague and subject only to limited qualitative analysis within an aggregative framework find a precise theoretical specification, subject to quantitative analysis, within the more disaggregative formulation. Examples of such concepts are division of labor, production bottlenecks, factor intensity, and the concept of structure of an economy. Some disaggregative models are presented in this chapter to illustrate the above point. These are models of "structural analysis," "feasibility analysis," and the model describing the "Leontief paradox."

It is also observed that some concepts of the aggregative models such as the Keynesian multiplier analysis find a more useful expression within a more disaggregative model because here, in addition to the overall multiplier, sectoral multipliers are calculated as well.

The fundamental conclusion of Parts I and II is that a disaggregative formulation that generates the aggregative results as a special case is theoretically and empirically superior to the aggregative formulations which, in general, do not define their variables in relation to the immediately available data. Disaggregation is one possible strategy toward the goal of defining variables in terms of factual materials and making this definition internal to the model--an inseparable part of it.

Chapter VIII applies this disaggregative theory formulation to a simple version of the quantity theory of money. Sectoral stocks and velocities of money are defined and it is shown that the overall velocity of money is a weighted average of the sectoral velocities, the weights being the relative stocks of money in the various sectors of the economy.

This implies that a very volatile overall velocity is fully consistent with more or less stable sectoral velocities. As far as this author has been able to determine this approach to the concept of velocity of money has not been taken before.

Some problems of empirical implementation of this model are examined and also some directions for expanding the explanatory scope of the theory are proposed.

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