

READINGS IN INPUT-OUTPUT ANALYSIS

Theory and Applications

EDITED BY IRA SOHN

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IRA SOHN

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Foreword

Input-Output has been steadily gaining recognition as a useful and, in some instances, indispensable tool of economic inquiry. Practical application of this relatively new analytical technique is advancing in the United States more rapidly than its adoption as a subject of academic instruction, hence the absence of easily accessible teaching material.

The purpose of this volume is to provide students and researchers with a single source for some of the best work that has been done in input-output economics over the past several decades. The twenty-eight articles collected here for the first time in one volume appeared originally in a great variety of economic journals and conference proceedings volumes, some of which are now out of print. They were selected from among many papers published annually on input-output analysis for their importance either as theoretical contributions to understanding the basic properties of static and dynamic input-output models, or as representative examples of practical applications of that flexible tool in areas as diverse as the study of the economic structure of metropolitan areas and analysis of the competitive position of Japan.

Dr. Ira Sohn, who made the selections and wrote the introductory chapter, was closely associated with me for a number of years as a member of the Senior Research staff of the Institute for Economic Analysis at New York University.

Wassily Leontief

Acknowledgments

As any fledgling student of input-output analysis is apt to quickly learn, the indirect effects stemming from a policy change are often as powerful as the direct effects of that stimulus. In attempting to apportion credit to those who have been instrumental in the publication of this volume, the contributions fall into two categories: direct and indirect.

I would like to acknowledge my debt to the scores of graduate students in the input-output course at New York University, whose repeated and amplified complaints over a period of seven “lean” years provided the direct incentive to conceive this volume. Regrettably, Stendhal’s dictum, “Il n’y a pas de force que la force” (“There is no force but force”), seems all too accurate in this instance. In atonement for past transgressions I hope that this book will provide future students and practitioners of input-output analysis seven (and even fourteen) “bountiful” years of use!

I would like to express my thanks to Professor Wassily Leontief, who permitted me to climb mountains—enabling me to both broaden and deepen my understanding of the ever-evolving economic landscape, which is shaped by technological, social, political, environmental and financial forces. I hope the selections in this volume adequately illustrate this panorama from the summit.

And last, and needless to say, not least, I am indebted to those responsible for overseeing this volume of readings as it progressed from its pre-manuscript form to bound books. In particular, I would like to thank Herbert J. Addison, Vice-President and Executive Editor, Ellen B. Fuchs, Managing Editor, and Wendy Warren Keebler, Associate Editor, all of Oxford University Press, and Mona Wong, previously at the Institute for Economic Analysis, and now also at Oxford.

Editor's Note

Since all the articles in this volume were either published previously or presented at scientific meetings, I would like to clarify at the outset the editorial changes that were introduced into the text.

Differences in American and British spelling were retained throughout, but punctuation has been changed to conform to American style.

All figures, tables and equations were renumbered, and some figures and tables were redrawn.

All footnotes were placed at the end of each contribution.

Text references were standardized throughout the volume.

In addition, when typographical or syntactical errors were discovered in the different articles, they were corrected.

I hope these modest changes have improved the coherency of the volume and, as a result, have enhanced the fluency of the book.

I.S.

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READINGS IN INPUT-OUTPUT ANALYSIS

Introduction

IRA SOHN

When I was first asked by Professor Leontief to begin reviewing the literature on input-output analysis with a view toward selecting a small subset of that literature for a volume of readings, my initial reaction was, "It's about time!" On further reflection, and with the hindsight of a preliminary survey (as opposed to a census) of the input-output literature, I concluded that "it couldn't be done." With the body of input-output literature now more than a few thousand books and articles strong, I was confronted with the following issues during the nominating process: Which criteria would have to be invoked so that only thirty or so of the articles could be selected for inclusion in this volume? And what compromises would have to be struck in order to insure that this collection (well under 1 percent of the estimated population of articles) exhibits a balance concerning the choice of topics, uniformity regarding the high quality of the papers, and relevance with respect to the subjects addressed. Whether or not this unenviable selection task was successfully accomplished only its readers can judge.

Objectives of the Volume

The purpose of this collection is two pronged: first, as an educational tool for students of economic modelling in general and input-output analysis in particular; and second, as a reference guide for practitioners of input-output analysis.

For the past seven years I have assisted Professor Leontief in teaching a graduate-level course in input-output analysis at New York University. Each year, every new crop of students would voice the same collective complaint a few weeks into the semester: "Isn't there a self-contained book on the subject that covers the topics in the course syllabus and also provides both background and supplementary reading materials?" Perennially, my response would be, "Not yet." This volume provides a first step toward equipping students with adequate course materials which are "under one roof." A companion volume by Leontief, consisting of a collection of some of his past and more recent articles, has also been published.¹ Together, they should provide the student with the necessary reading materials from which he or she can go on to "do" input-output analysis either by extending its methodological frontiers or by adding to its empirical applications.

To carry out the second purpose for assembling this anthology (i.e., as a

reference guide for practitioners of input-output analysis), the subjects which comprise Parts II and III of the volume were chosen to address most of the problems that users of input-output analysis are likely to confront: issues related to classification, aggregation, by-products, changes in coefficients, and projections for national and regional economies. In addition, some examples of the uses of the input-output approach as a tool of economic analysis are presented in the last part of this anthology. While many of the so-called state-of-the-art papers can be found in recent journals, the articles selected for this volume present, in some cases for the first time, the cause and nature of the problem studied and *a* (rather than *the*) solution using the context of the input-output approach. For those with an interest in the history of economic analysis, this collection should be of special value since, to some extent, it traces out the evolution of a relatively new and specialized methodology as it has developed over the past forty years.

Restrictions on the Selection Process

A few words are appropriate concerning the self-imposed restrictions placed on the selection process. First of all, this collection is limited to articles that first appeared in, or were later translated into, English. While many studies using input-output analysis are undertaken and published by statistical offices and research centers in many non-English-speaking countries, the contents of these studies often find their way into an English language publication, either directly or through some intermediary, such as an international forum. (Appropriately, I believe it was Max Born who once remarked that it was not English—but *broken* English—that was the real international language of science!)

Second, even though Leontief has written at some time in his long career on almost all of the above subjects, his contributions were deliberately omitted from this volume. Leontief's name has been so strongly associated with input-output analysis that the two have been used interchangeably. While it may be accurate to say that Leontief is synonymous with input-output analysis, the selections that comprise this volume should go far to dispel the notion that input-output analysis is Leontief and only Leontief.

Third, I have attempted to strike a balance between some of the now "classic" literature in input-output analysis and the more recent developments in the field. Some may be of the opinion, after scanning the table of contents, that I have had an excessive bias for the "classics" and have not, therefore, sufficiently discounted the past. (More about this below.) Also, I have sought to provide a reasonable complement of input-output studies which, on the one hand, articulate methodological issues and, on the other, exemplify empirical ones which, as might be expected, lend themselves more to economic policy analysis.

In addition, the selections in this reader have been restricted to articles that have appeared in journals and periodicals or have been presented at scientific conferences (some of which were subsequently published in a volume of proceedings.)² Even after considering all of the above restrictions—most of which are nonintersecting—the number of remaining candidates from which a final

selection was made depended ultimately on space considerations. Therefore, given the various (and very different) constraints within which I permitted myself to roam in the selection process, I believe (or, at the very least, hope) that this brief anthology captures the spirit and the body of this still fresh and innovative approach to describing and analyzing some of the issues with which economic science concerns itself.

Organization of the Volume

The articles selected were subdivided into three general groups: national and regional studies, studies on the coefficients matrix, and economic analysis using the input-output methodology. Preceding these groups of articles is a short survey—a brief progress report on the technique—by the recent Nobel laureate, Professor Sir Richard Stone of Cambridge University who has been a leading proponent of the input-output approach in the United Kingdom for over thirty years.

Leontief's pioneering study, *The Structure of the American Economy 1919–1929*, published in 1941, reconstructed the flows between industries and to the component parts of final demand for the U.S. economy for 1919–1929. With this basic framework in place, the seeds bearing the fundamental questions that input-output analysis was designed to answer began to sprout. Subsequent studies addressed questions of resource availabilities and sectoral capacity constraints for a given technological base and levels of final deliveries. Since the number of unknown variables always exceeds the number of independent equations in a so-called open input-output system, these questions can always be turned on their head. For example, given resource availability, sectoral capacity levels, and a technological base, for a given *structure* of final demand what *levels* of final demand can be attained? More generally, the introduction of the use of input-output analysis into statistical offices in many different countries afforded those designing national economic policy alternatives a real laboratory for assessing and analyzing these alternative policies. For the first time, detailed, quantitative projections at the sectoral level—computed in an internally consistent way, side by side with the national accounts—could be used to formulate macro- and microeconomic policies that were feasible within the set of national constraints (i.e., a given technological base, available labor force, sectoral capacity levels, available foreign exchange, etc.). One of the first countries to use input-output analysis in this context was Norway in the early 1950s when it was used as an analytical tool to aid in the reconstruction of the Norwegian economy in the postwar era. The important role that input-output analysis continues to play in the formulation of Norwegian economic policy is demonstrated in the article by Bjerkholt.

To date about 90 countries have constructed input-output tables. These countries include the Socialist-oriented economies, the Western market-oriented countries, and an increasing number of developing countries. Included in the section on national and regional studies in this volume are contributions that describe the current use of input-output analysis in some of these countries (Bjerkholt, Buckler et al., Miernyk, Polenske, and Bulmer-Thomas).

As the use of input-output analysis became more and more institutionalized throughout the world, it was inevitable that some standardization of conventions would become necessary. The article by Aidenoff describes the basis for the integration of input-output analysis into the system of national accounts (SNA) adopted by the Statistical Commission of the United Nations. This was an indispensable contribution to implement the global modelling efforts begun by Leontief, Klein, and Tinbergen, and their associates, and Almon, Bottomley, and others during the 1970s and up to the present time. The first section ends with an article by Stone on the incorporation of demographic factors into the input-output framework. Those working with input-output models are aware that for a given technological base [consistent with the Simon-Hawkins conditions (see below)] and a *structure* of final demand, *unique* output levels—rather than output ratios—can be determined only after the relevant demographic information is incorporated, either directly or indirectly, through *levels* of final demand. While the role played by technological change and/or changes in consumer preferences over time (in response to relative price changes among other things) is central to any discussion of long-term economic change, most growth in sectoral output levels over time can be attributed to population dynamics. One does not need to be a prophet to predict that the “funeral business” will be a high-growth sector of the U.S. economy in the year 2020–2030 if current actuarial figures are to be relied upon. Also, due to the “echo” of the postwar “baby boom” in the United States and Europe, the late 1980s and the last decade of this century should prove to be “boom years” for the primary and secondary education sectors. Again, this is nothing more than the normal course of population dynamics making itself felt.

Ultimately, if the economy is about anything, it is about people—how they live, what they eat, how they earn their income, what they buy, how they spend their leisure time, etc. The input-output table fills in the details to provide answers to these questions by linking the consumption and distribution activities with the production ones. The article by Stone links these demographic aspects with the economy, and, in that way, enables users of input-output analysis to incorporate explicitly the single most important factor that determines the *level* of sector inputs, sector outputs, and final output—people.

The second set of articles is devoted to studies of the coefficients matrix, the heart of the input-output model. Those who are familiar with the mechanics of input-output analysis are, in some cases, often painfully aware of the reason for an unsuccessful “run” of their model: “Something was amiss in the coefficients matrix.” Whether the disorder was diagnosed as a matrix with “rank problems” or one with “a bad condition number,” or one in which information was erroneously stored, the outcome is the same: the results of such a “run” are either nonsense and/or they cannot be guaranteed mathematically. Consequently, it should come as no surprise to input-output practitioners that so much attention was devoted to enumerating the formal properties of a “sound” coefficients matrix and its relationship with the bill of final demand. Around the early 1950s, these issues captured the interest (and time) of no fewer than five future Nobel laureates in economics: Kenneth Arrow, Gerard Debreu, Tjalling Koopmans, Paul Samuelson, and Herbert Simon. Their

pioneering work on the substitution theorem and the properties that the coefficients matrix must exhibit are reprinted below.

By the mid 1950s with these concerns satisfactorily addressed, the focus of interest in the coefficients matrix shifted to the problem of aggregation and the potential biases that this problem could introduce into the analysis. Economists were finally endowed with (or more precisely, were given the necessary tools to construct) a framework that could exploit the rich databases of technical information that government surveys and censuses provided. However, with large-scale computing hardware still in its infancy at that time, this detailed information could be made operational only in aggregated form. The responses to this obstacle spawned a vigorous flurry of technical articles on aggregation, one of which is reprinted in this volume (Fisher). The problem of aggregation is, in the end, very much like a chronic skin ailment—it can be diagnosed and even treated but never really cured!

In the 1960s and 1970s, once the data on technology introduced after World War II became widely available throughout the Western economies, much attention was directed toward: first, assessing the economy-wide economic impact of changing technologies (Sevaldson and Vaccara); second, methods, pioneered by Stone, to update and project input-output coefficients (Lynch); and third, refinements, extensions, and applications of the dynamic model introduced by Leontief in the mid 1950s (Almon, Fisher and Chilton, and Johansen). The question of incorporating, within the input-output framework, the treatment of by-products or secondary products in the production process, or (in some cases) the equivalent of producing a single product using alternative methods of production also captured the interest of input-output theoreticians and practitioners in the 1960s (Almon).

The last section of this volume is devoted to articles that apply the input-output methodology to empirical problems requiring economic analysis. Linear growth models (as they are conventionally defined) had their genesis in J. von Neumann's pathbreaking article that was first published in 1937 and which appeared in translation in 1946 as "A Model of General Economic Equilibrium."³ (P. Sraffa's, *The Production of Commodities by Means of Commodities*, though conceived in the 1930s, did not appear in print until 1960.) While the theoretical underpinnings of Leontief's input-output system were shown to be a special case of the more general von Neumann construct, the real strength of the input-output methodology lay not in its theoretical foundation but rather in its practical uses as an implement of economic analysis. In some cases input-output analysis has been used as just one more instrument in the economist's toolkit (e.g., for projecting GNP or sector output levels). For other uses, it occupies a unique position as an analytical device that has helped economists and policy makers to describe and quantify the tradeoffs that are inherent in any set of feasible policy alternatives. For example, the empirical work undertaken in response to its pioneering use in the description and analysis of U.S. imports and exports in the 1950s (the so-called Leontief Paradox) generated an extraordinary influence on advancing the measurement of factor intensity in production in general, and of our understanding of the changing position of the national economy within the wider framework of the world

economy in particular. The articles by Heller and Riedel exemplify these advances in our understanding: the former provides evidence of the changing role played by the most developed Asian country—Japan—and the latter demonstrates the economic rationale for the heavy reliance of Taiwan on imported materials to fuel the development and industrialization process that began in the early 1960s and is continuing today.

The practical demonstration of the input-output methodology for the description and analysis of regional problems has provided regional economists and other regional scientists the ability to focus their attention on economic activities within a well-defined spatial environment, while at the same time continuing to track the larger and often more dominating economic activities that surround the regional economy. The article by Hirsch, written over 25 years ago, reports on one of the first regional input-output tables produced which had as one of its objectives “to develop more adequate methods for a better understanding of the economic fabric of a metropolitan area.” Regional input-output analysis had its genesis in the work of Isard in the early 1950s; today in the United States, it is firmly institutionalized in governmental and quasigovernmental agencies such as the Port Authority of New York and New Jersey, aside from the studies undertaken in many university and private research centers.

One of the first major studies involving international comparisons of the structure of production which utilized the tool of input-output analysis was carried out by Chenery and Watanabe in 1958 (*Econometrica*, Vol. 26, no. 4, October 1958, pp. 487–521). The objective of this type of analysis was, in the words of the authors of this now “classic” article, to “shed light on the bases for international trade, the mechanism of economic growth and other economic problems whose understanding requires an empirical knowledge of the nature of interdependence.” Two subsequent studies, both of which appeared in 1965 and are reprinted in this volume, extended the work of Chenery and Watanabe to gain new insight into the industrialization and development process. The paper by Simpson and Tsukui demonstrated “that the economic systems of Japan and the United States, although superficially dissimilar, contain almost identical patterns of industries which are strongly inter-related.” Their findings suggest “that there are certain fundamental elements which may be found in the productive structure of modern economic systems which are purely technical in character.” This latter suggestion is precisely the objective of the paper by Yan and Ames. They used input-output data as the basis for “testing empirically a variety of assertions made about certain tendencies in the economic history of industrializing economies.” The article by Weisskoff and Wolff is a lineal descendant of the work of Chenery and Watanabe. In this case, the authors set out “to measure the net effects of the industrialization process on the structure of import flows and to examine the resulting changes in import dependence” for Puerto Rico.

If the problems of the debt crisis in some of the developing countries and trade protectionism in the developed countries emerged as the central economic issues of the first half of the 1980s, then the energy crisis and questions about the environment could qualify as the major subjects of concern to economists in the 1970s. (The accelerated rates of inflation which plagued the western developed