

## Preface

The micro half of international economics is surprisingly sparse in empirical work. It is difficult to name another substantive field in economics in which theorists make such great efforts to identify the unending stream of logical possibilities, and in which so little effort is made to attach empirical probabilities to their many models. Courses and books proudly use what seems to be a pejorative title, "pure theory," adopting "unstained" as the definition of "pure," rather than the alternative "mere."

This book is intended to be an empirical supplement to the traditional courses that offer mere theory. As is the case with all empirical exercises in econometrics, plenty of stains will be provided as well. Unlike many empirical researchers, I have gone to considerable effort to point out the stains that arise when the neat theories are translated into precise statements about a cluttered reality. I have tried to demonstrate what results are acceptably insensitive to the incredible assumptions that theoretical econometricians expect analyzers of data to make, and what results are not.

The scientific goal of this book is to leave the reader with a clear impression concerning the empirical validity of a central result of trade theory—the celebrated Heckscher-Ohlin theorem. This theorem, in its most general form, states that a country's trading relations with the rest of the world depend on its endowments of productive factors, usually identified in theory textbooks as land, labor, and capital. A second, but equally important, goal of this book is to describe succinctly and clearly the patterns of trade and the patterns of resource supplies of as many countries as the data permit. This will make the book a useful reference, whether or not it offers convincing evidence concerning the Heckscher-Ohlin theorem.

This book is not an exercise in pure empiricism. It is impossible to do any empirical work without some form of theoretical structure for selecting which variables to observe. But the use of a vague intuitive theory merely to select the variables to observe is not enough, since intuitively plausible empirical work can be completely inappropriate when viewed through the lens of a fully articulated theory. The two most frequent forms of empirical study in trade are excellent examples of this. Both the Leontief-type factor content studies and the cross-commodity regressions of net exports on factor intensities use intuition to generalize the 2-dimensional Heckscher-Ohlin theorem to a multifactor multicommodity reality.

uncomfortable. This strikes me as the main reason why Bayesian methods are rarely used, though sheer ignorance plays a role as well. It is my hope that this book will serve as an example of a convincing, sensible data analysis using Bayesian methods and will encourage others also to use these methods. The uncomfortable feeling that necessarily attaches to the selection of the fictitious prior data set is combatted by a sensitivity analysis. The computer program SEARCH, which was used to do these calculations, is available on request.

Chapter 6 reports a statistical analysis of the relation between the 10 trade aggregates and 11 resource supplies. The Heckscher-Ohlin model has content only at an empirical level when one must select a list of measurable immobile resources and a functional relation between trade and these resources. The model that results is necessarily incredible because of limitations on both the list of resource variables and the family of functional forms. A judgment about the success of an empirical study of an approximation to a tautological theory is ultimately a matter of aesthetics. The general proposition that trade depends on resource endowments is not testable. At best one demonstrates that the data can be organized so that there appears to be a relation between trade and some function of a set of measured resources. If the list of resources is "brief" and "sensible," if the functional form is "plausible," and if the relation is "close," an empirical study will surprise and amuse.

I believe chapter 6 demonstrates that the main currents of international trade are well understood in terms of the abundance of a remarkably limited list of resources. In that sense the Heckscher-Ohlin theory comes out looking rather well. No real test of the theory is presented here because no alternative is fully articulated. Therefore you must judge the results as support for the theory if you are surprised by the quality of the explanation this abbreviated version of the theory offers and if you doubt that a fully articulated alternative could do as well or even add much to the understanding already achieved. The resulting image of the workings of the economy is admittedly cold and mechanical. Neither Henry Ford nor Vladimir Lenin plays a role. Nor does Thomas Edison, Karl Marx, Adam Smith, Queen Victoria, Christ, or Mohammed. . . . What distinguishes countries from one another is only their natural resources, work forces, and savings rates. But this mechanical explanation seems surprisingly complete, and the anomalies not explained by this limited list of resources

do not elicit a feeling that Ford, Lenin, Edison, Marx, . . . have much impact on the structure of international trade.

Perhaps the most interesting finding is the reversed role from 1958 to 1975 of knowledge capital and physical capital as sources of comparative advantage in manufactured products. In 1958 the most highly skilled laborers contributed to comparative advantage in all four manufactured aggregates, but in 1975 these workers contributed positively to only the most skill intensive manufactured aggregate (chemicals). Conversely, in 1958 physical capital was a source of comparative advantage only in chemicals, but in 1975 it contributed positively to all four of the aggregates of manufactures. Another interesting finding is that coal production in 1958 was a source of comparative advantage in manufactured products, but that by 1975 this effect had reversed itself. Otherwise, the results are what you would expect: Unskilled labor and land are sources of comparative advantage in the agricultural products, and natural resources are sources of comparative advantage in the natural resource products.

In the last chapter of this book, chapter 7, the estimated model is used to study two counterfactual questions: (1) What change in trade would have occurred if the world's resources were rearranged? (2) What change in the functional distribution of income would have been induced by a change in tariff rates? The study of the first question allows us to identify the resources that were the most important determinants of trade. One finding is that physical capital and petroleum production in 1975 were the most critical resources, in the sense that trade could have been greatly reduced if they were reallocated. An explanation of this finding is that a large amount of international trade in 1975 amounted to the exchange of manufactured commodities for oil. In 1958, in contrast, trade is discovered to have been due principally to the uneven distribution internationally of the most highly skilled workers, other workers, and a type of land, in that order. Answers to the second counterfactual about the effect of tariffs on the functional distribution of income are based on Samuelson's reciprocity relations, which allow us to interpret the estimated derivative of outputs with respect to resource supplies as derivatives of factor returns with respect to product prices. These inferences are to be suspected for their indirectness, but they are amusing for their subtlety.

From my perspective there are several important shortcomings of this effort that I have been unable or unwilling to remedy. Most important,

Unfortunately, that intuition is incorrect, and the consequent empirical work is limited in value, as is argued in chapter 2.

The need for a fully articulated theoretical foundation for this study of trade data is met in chapter 1, which reviews the standard theory. Much of this chapter can be found in the standard texts, but some of it cannot; my empirical perspective forces the inclusion here, in the midst of a theoretical discussion, of various complications not often treated. This perspective is also useful since it forces one to limit or to eliminate empirically irrelevant theory. The need when doing empirical work for a fully defined mathematical model has dictated the adoption of the Heckscher-Ohlin-Vanek (HOV) model as the maintained hypothesis of the data analysis. A distinctive feature of chapter 1 is the algebraic development of trade theory as implied by the HOV model. For example, the Heckscher-Ohlin theorem is shown to be a consequence of the sign pattern of the inverse of a  $2 \times 2$  positive matrix. My impression is that this chapter makes useful supplementary reading for students who have studied other approaches. I have also included in this chapter several tables of cross-national comparisons that indicate the extent to which such hypothesized relations as factor price equalization actually apply.

Chapter 2 is of a transitional character; it deals with what it means to test a theory when it is clear at the outset that the theory is not perfectly correct and when alternative theories are impossible to state precisely. The conclusion reached in this chapter is that it is possible to measure the accuracy of the theory but that the decision whether the theory is accurate "enough" must remain a matter of aesthetics and judgment. I have also provided a brief critical review of attempts in the literature to test the Heckscher-Ohlin theorem. These tests have all floundered for lack of an appropriate statement of the theorem applicable to a multifactor multigood reality.

Chapter 3 deals with the formation of trade aggregates. The number of traded commodities is much too large to allow analysis of each separately, and the first empirical step in this study will be to decide on some level of aggregation. The SITC grouping (Standard International Trade Classification, Revision 1) has 10 "1-digit" commodities, 69 "2-digit" commodities, and 182 "3-digit" commodities. At the 5-digit level one finds details such as "pineapples," "human hair," "cigarette paper," and "scissors." The lowest level of aggregation that is considered here is the 3-digit level. For ease of study and clarity of communication I wanted to

work with 10–20 commodities. I was uncomfortable merely adopting the SITC 2-digit level since I suspected that the SITC scheme camouflaged major features of the more disaggregated data. I therefore formed my own aggregates from the 2-digit SITC data, and in one instance I checked the quality of these aggregates further by studying the 3-digit data. The 10 aggregates that I use are 2 primary products, 4 crops, and 4 manufactured goods.

Chapter 4 offers a view of the data that may prove more memorable than the econometric results presented subsequently. I have worked hard to devise tables and graphs that illustrate the salient features of the data. Included in this chapter are correlation matrices and boxplots. Also included in this chapter are discussions of trade dependence and resource abundance profiles, which may be found in appendix D. The trade dependence profiles illustrate the composition of net exports of the 10 trade aggregates relative to GNP. The resource abundance profiles illustrate the relative abundance of 11 different resources that are hypothesized to be the sources of comparative advantage. These profiles are provided for all countries in both 1958 and 1975. Some may argue that these displays are the most useful part of this book in that they provide a clear picture of the world's trading relations that is not available anywhere else.

Econometric methods are the subject of chapter 5. I am primarily a theoretical econometrician, and I have used this book as a showcase for some of my ideas. The basic theme of my theoretical work has been that a statistical analysis requires incredible assumptions and should be ignored unless the inferences are shown to be adequately insensitive to the choice of assumptions. Chapter 5 accordingly discusses the theory of sensitivity analyses that deal with gross errors, heteroscedasticity, chronic errors, and multicollinearity, all of which plague analyzers of cross-country data sets.

I have something of an ulterior motive for writing this book. I am a committed Bayesian, which means that I think it is silly to act as if human judgment had no effect on data analyses. On the contrary, any sensible, convincing analysis of economic data has economics as a major input. A Bayesian analysis has a formal procedure by which economic judgment can be introduced into the data analysis. It treats opinion as equivalent to a previous hypothetical data set. At a purely logical level the Bayesian theory is compelling, but when this method is actually applied, conjuring up all the features of the fictitious prior data set can become distinctly

I would have liked to have studied an alternative theory that explains trade in terms of scale economies, and I also would have liked to have used better measurements of the resources, especially physical and knowledge capital. Though it is beyond the scope of the present effort, a study of the dynamics of comparative advantage may well prove fruitful. In this book, cross-country comparisons of 1958 data and 1975 data are made separately, and no attempt is made to pool data across years.

Also from my perspective, this book makes three significant contributions. It provides a clear and complete statement of the theory of international comparative advantage and carefully links that theory to the empirical work. It provides illuminating data displays that will serve as a most convenient source of information about the international economy. And it presents a convincing data analysis using tools on the frontier of econometric theory in ways that are both understandable and sensible. Naturally, I hope the reader agrees.

Reading and understanding everything in this book will be a formidable task for most people. Chapters 3 and 4 and appendixes C and D, which summarize and display the data, are quite accessible; advanced undergraduates should find them readable. The economic theory presented in chapter 1 is perhaps a shade more mathematical than the more popular texts, but graduate students in economics ought to be able to handle the simple matrix expressions that appear there. The data analysis will perhaps cause the greatest problems, not because the procedure is truly complex, but only because it is unfamiliar. I have tried to deal with this by including a chapter on econometric methods that should be quite understandable to anyone who has had a course on the linear regression model.

It is not necessary to read the book in its entirety. The least mathematically sophisticated reader should find the trade dependence and resource abundance profiles in appendix D to be very informative summaries of the composition of trade and resource endowments. These displays are suggested by the Heckscher-Ohlin-Vanek model, and it would be wise for the reader to master at least the simplest  $2 \times 2$  version of that model; this is described in section 1.2. The least sophisticated reader will also find the scatter plots in appendix C interesting, since they reveal in many cases a clear relation between trade composition and the resource endowments. Most of the rest of the book presupposes familiarity with simple matrix manipulations and introductory econometrics. It is suggested that the chapters be read in sequence, though much of the

theoretical development in chapter 1 can be skimmed because it is not used directly in the data analysis.

Data collection and the analysis reported here have been supported by Ford Foundation grant 775-0692 and by Labor Department contract J9K80007. Work on the innovative econometric techniques used here has been funded by NSF grants SOC78-09479 and SES82-07532. Several UCLA graduate students have assisted on various phases of this project. The list includes Harry P. Bowen, Kenneth Tamor, Nancy Kane, Cary Knadler Morris, Eduardo Perez Mota, Jon Williams, and Robert Peterson. Harry Bowen and Sebastian Edwards made many useful comments on several of the chapters. Special thanks are offered to the anonymous referees, whose comments were especially useful.

## General Notation

$A$	$m \times n$ matrix of factor input requirements with elements $A_{ij}$
$B$	$n \times n$ matrix of intermediate input requirements
$C$	$n \times 1$ vector of consumption of final goods
$F$	production function
$f$	output per worker
$f'$	first derivative of $f$
$K$	capital
$L$	labor
$M$	land
$k$	$K/L$
$p$	$n \times 1$ vector of commodity prices
$Q$	$n \times 1$ vector of production levels
$s$	consumption share
$T$	$n \times 1$ vector of net exports
$X$	$n \times 1$ vector of final outputs
$Y$	gross national product
$V$	$m \times 1$ vector of factor endowments
$w$	$m \times 1$ vector of factor prices

## Subscripts

$i$	factor; $i = 1, \dots, m$
$j$	commodity; $j = 1, \dots, n$
$c$	country; $c = 1, \dots, p$
$w$	world