

Global Trade Analysis

Modeling and applications

Editor

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I dedicate this book to my wife, Adriela, whose enthusiastic support of this effort has been essential to its success, and to my children, Alexander and Sarah, who have generously shared their father's time with a third child, named GTAP.

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Inspiration for GTAP derived from my 1990–1991 sabbatical year with the Impact Project in Melbourne, Australia. Our stay in Melbourne was hosted by Alan Powell and Ken Pearson, who were most generous with their time and support. Alan's work with Impact demonstrated to me that applied general equilibrium analysis could indeed have a lasting effect on public policy. His guidance in getting GTAP off on the right foot was invaluable. The collaborative relationship with Ken Pearson that emerged from this sabbatical has proven most fruitful, forming the basis for operationalizing the GTAP model. Ken has proven to be an essential ingredient in the highly successful short courses.

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Foreword

Economics, perhaps more than any other area of social inquiry, aspires to the status of a science. Like astronomers, we economists acknowledge that our inability to conduct controlled experiments puts us at a disadvantage. But instead of minimizing this disability, all too often we have accentuated it by failing to implement those straightforward measures that are taken as routine in the physical sciences. In particular – and as was forcefully pointed out by Dewald, Thursby, and Anderson in the *American Economic Review* (AER) for September 1986 – we have not even taken the standard precautions needed to ensure that our work can be replicated independently by others.

What is required to ensure replicability? The editors of the AER, in the issue referred to above, announced that it was their policy to “publish papers only where the data used in the analysis are clearly and precisely documented, are readily available to any researcher for purposes of replication, and where details of the computations sufficient to permit replication are provided” (p. v). In the case of applied general equilibrium (AGE) work, this can amount to a tall order.

To take just one well-known example – the Australian ORANI model – a listing of the model’s data base and parameter file runs to 646 pages (Kenderes and Strzelecki 1991). The equations of the model itself, their interpretation and illustrative simulations are documented in a 372-page monograph (Dixon, Parmenter, Sutton, and Vincent 1982), and in a journal literature too voluminous to cite here.

Given that a practical AGE model involves a very heavy investment of intellectual effort and data-garnering, it would be amazing if economists did not recognize the potential for economies of scale and scope. The realization of such economies requires the proprietor of a model building effort to see most of the model’s core ingredients – such as its standard or default equation listing, data base, and parameter file – as public goods. Around such publicly

(or semipublicly) available tools we would expect a community of modelers to develop. Yet such has tended to be the exception rather than the rule.

The Global Trade Analysis Project (GTAP) is such an exceptional venture. At the outset of the project, its founder and director, Tom Hertel, decided that the issues involved in global trade are too important, and the resources available to support research too few, for current opportunities to be squandered by engaging in the wrong sort of replication while failing to attend to the prerequisites listed above for the right sort of replication. By the "wrong" sort of replication I mean unnecessary duplication: that is, two or more individuals or groups making separate demands on research resources to produce essentially the same product, be it a data base, a parameter file, or a core model.

Most of the resistance to sharing resources in AGE modeling can be traced to just two sources: (1) funding difficulties and (2) the academic imperative. If a common, open-access research facility is to be created, how does one elicit enough cooperation among the potential clientele to ensure that attempted free-riding does not sink the initiative? If academic recognition, promotion, and tenure seem to be more available to "loners" who keep their research cards very close to their vests, how can a community of modelers develop around a common modeling resource base? The answer to the first question clearly is that all putative members of a research consortium must recognize that without cooperation all are likely to be worse off. Having faced up to this, they must then agree to behave as responsible members of the modeling community. This implies meeting a share of the funding where possible, and agreeing that modeling infrastructure developed in-house will be shared by all.

The academic imperative will remain an obstacle as long as promotion and tenure committees – not to mention referees and editors of journals in applied economics – continue to reward novelty at the expense of the usefulness of research outputs. Over time I believe we are seeing more and more AGE researchers in academia realize that a quality piece of applied analysis that builds on an existing core model and data base offers better professional opportunities than implementing some new twist for its own sake on a toy model with data of doubtful provenance and relevance to any real-world problem. The chapters in this volume give grounds for hope that I am right about this.

The Australian community of AGE-oriented policy modelers was largely created at the Impact Project. Many key figures of the community either participated in some way in the development of the ORANI model under Peter Dixon and associates (1982) or else attended training courses organized by the project. Similar short courses are now being offered by the Global Trade Analysis Project. Such courses

- Give quick access to the core model, data base, and computing system
- Establish contact with a network of researchers having overlapping interests
- Give hands-on experience with manipulating a state-of-the-art model for policy analysis
- Serendipitously achieve many of the aims of refresher courses in economic theory and policy analysis

The story of the success of the family of ORANI-based models has been described at length in Powell and Lawson (1990), Vincent (1990), Powell and Snape (1992), and Dee (1994). It is an understatement to say that the utility of the approach was not immediately obvious to all players. The turning point in gaining acceptance by officials in policy agencies came when they realized that the AGE approach was not a straitjacket, but offered them enormous flexibility to apply their own insights into particular problems within a consistent economywide framework. This would not have been possible without generic software allowing modelers routinely to modify those parts of the ORANI theory that were not adequate to the task in hand, to eliminate unnecessary detail by aggregating over sectors/agents not currently under focus, and to amplify sectors of current interest by adding equations and data. The GEMPACK software suite developed by Ken Pearson and associates (see Harrison and Pearson 1994) put all this on a routine basis.

Apart from the importance of modeling flexibility to the clientele, and of human capital formation through training courses, other "lessons" gleaned from Impact's two decades of experience [as summarized by Powell and Lawson (1990) and Powell and Snape (1992)] suggest that a project that aims to provide the infrastructure for a focused modeling community should

1. Not be run entirely within a university or entirely within the client policy agencies
2. Be accompanied by full public documentation of data, methods, and results
3. Have detailed involvement of the policy clientele in the design stage of model building
4. Be at full arm's length from executive government

Recommendation 4 involves putting some space between the practitioner who is supplying the tools and the practitioner who is crafting the policy advice. The credibility of the tools should not be left too vulnerable to misjudgments by policy analysts or to the political popularity of particular policy recommendations based on them. Item 3, on the other hand, emphasizes that a policy-

oriented model will be of limited use if no policy adviser uses it with enthusiasm.

As noted in the list above, item 2 is simply a criterion for scientific work: results must be capable of replication. Where conflicting interests are at stake, it is unreasonable to expect opponents to accept the reasonableness of assumptions or the internal consistency of simulations without full documentation; moreover, they can be relied upon to invest considerable resources into unearthing any shoddy work. In any event, abiding by best scientific practice is the assurance of quality control. Item 1 recognizes complementarities between the discipline of a civil service environment, which encourages working to a preannounced research program, and the creativity of the academic environment, which does not.

Finally, sponsors need to be convinced that a computable general equilibrium (CGE) model, including its data base/parameter life and computer systems, like any capital good, is subject to both depreciation and obsolescence. An ongoing resource commitment is necessary for updating and refurbishment. Although the institutional setting and subject matter differ from *Impact's*, I suspect that these insights may be useful in guiding GTAP through its formative years. I would be less than honest, however, if I did not record my pleasure that GTAP's director sees the development of his own project (perhaps somewhat hyperbolically) as "taking *Impact* abroad" (Hertel 1994).

The research agenda ahead of GTAP will be driven by the energy and vision of its director, and by the research imperatives of all those who use the GTAP framework. The start is impressive, the fundamentals are right. Where policy advisers have vision and are prepared to back that vision by cooperating in the development of a common research infrastructure, the results can be spectacular (as I believe the Australian experience shows). Hardheaded (or at least shrewd) decision makers will not let bureaucratic or academic imperatives encumber the development and use of powerful tools in the crucial task of sharpening the debate about world trading arrangements.

Alan A. Powell

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PART I

INTRODUCTION AND OVERVIEW

Introduction

Thomas W. Hertel

What is GTAP?

The Global Trade Analysis Project (GTAP) was established in 1992, with the objective of lowering the cost of entry for those seeking to conduct quantitative analyses of international economic issues in an economywide framework. The project consists of several components:

- A fully documented, publicly available, global data base
- A standard modeling framework
- Software for manipulating the data and implementing the standard model
- A global network of researchers, linked through the Internet, with a common interest in multiregion analysis of trade and resource issues
- A World Wide Web site for distributing software, data, and other project-related items of interest
- A consortium of national and international agencies providing leadership and a base level of support

Part II of this book documents the GTAP model structure, data base, and software. Part III contains seven applications of the model. These are all available through GTAP's Web site, and the interested reader will have the opportunity to access, replicate, and extend these applications using the software described in Chapter 6.

Motivation for GTAP

As the world economy becomes more integrated, there is an increasing demand for quantitative analyses of policy issues on a global basis. One example is provided by the Uruguay Round negotiations, which took place under the auspices of the General Agreement on Tariffs and Trade (GATT). There has

been great interest in estimates of the impact of this agreement on individual countries, international trade, and worldwide welfare. Sector-by-sector analyses are a valuable input into this process. However, by its very nature, the GATT affects all sectors and most regions of the world, so there is no way to avoid employing a data base that is exhaustive in its coverage of commodities and countries. A similar problem exists when one wishes to analyze the economic implications of climate change, economic growth, or any one of a number of issues affecting the world as a whole. GTAP aims to facilitate such multicountry, economywide analyses.

GTAP data base

The central ingredient in GTAP's success to date has been the global data base, described in detail in Chapters 3 and 4. This data base contains bilateral trade, transport, and protection data characterizing economic linkages among regions, together with individual-country input-output data bases that account for intersectoral linkages within each region. (See Chapter 3, Table 3.1, for a complete list of regions and commodities in version 2 of the GTAP data base.) The construction and maintenance of this data base adheres to the following principles:

Public availability. The data base is made available to anyone requesting it, at cost. This prevents needless duplication of effort in creating this public good. In particular, existing aggregations of the data base are provided for free, via anonymous FTP on the internet. New aggregations can be ordered, for a nominal fee, and are then added to the FTP site. Finally, the full data base may be purchased, along with documentation and software, by those interested in performing their own aggregations.

Annual upgrades. The data base is upgraded annually. Typically, this involves adding more regions as well as improving the quality of the data base for existing regions. Periodically we update the base year and in the future, the commodity aggregation may change. The data base used in this book is the second release (version 2) of the GTAP data base.

Broad participation. The network of GTAP users represents an excellent resource for scrutiny and improvement of the data base. Those who identify areas for improvement or extension of the data base are encouraged to contact the GTAP staff with their ideas so that they may be considered for incorporation into the next year's data base. The operational concept is, "If you don't like it, help fix it!"

Comparative advantage. By making the full data base available, and by incorporating improvements offered by members of the network, each individual is able to work to his or her comparative advantage, while capitalizing on the contributions of others.

Documentation and replicability. The data base is fully documented. One requirement for new contributions to the GTAP data base is that the sources and procedures used to create them be provided along with the data. In addition, the GTAP software is designed to permit applications to be readily replicated by others (including the readers of this book). Together these two features are designed to enhance the credibility and comparability of global trade analyses.

Model and software

In order to operationalize this large data base, a standard modeling framework has been developed. The theory of this multiregion, applied general equilibrium model is developed in Chapter 2. Distinguishing features include: the treatment of private household behavior, international trade and transport activity, and global savings/investment relationships. Also, a number of auxiliary variables have been introduced in order to facilitate alternative closures, including *partial equilibrium* specifications aimed at facilitating comparisons with other models.

The standard GTAP model is implemented using Release 5.1 of the GEMPACK software suite, developed at the IMPACT Project, Monash University, under the direction of Kenneth Pearson, with the support of the Australian Industry Commission. The software described in this book, and available at no cost from the FTP site, is referred to as the *GTAP Book Version of GEMPACK*. This permits the reader to conduct *nonlinear* simulations of the standard model in which changes in policy, technology, population, and factor endowments are examined. The user specifies the split between exogenous and endogenous variables (i.e., model closure). Behavioral parameters may also be altered. Outputs include a complete matrix of bilateral trade, activity flows (and percentage changes) by sector and region, private and government consumption, regional welfare, and a variety of summary variables. Users with access to a source-code version of GEMPACK may also modify the theory of the model.

At the time of publication of this book, literally dozens of applications of the standard GTAP framework were under way, worldwide. These are aimed at addressing a great variety of issues including: trade policy reform, regional integration, energy policy, global climate change, technological progress, and historical analysis of economic growth and trade. Seven of these applications have been selected for inclusion in this book. They are intended to be representative of some of the types of work for which GTAP is currently being used.

These applications can be accomplished using the standard GTAP model, the software for which is on the FTP site.

Short course in Global Trade Analysis

Use of this framework has spread quickly around the globe. Only two years into its existence, the framework was being used on five continents, by a wide variety of researchers in academia, public agencies, and even the private sector. A great deal of credit for this must be attributed to the annual Short Course in Global Trade Analysis. This was an innovation adopted from the Impact Project that introduced such a course 20 years ago to encourage use of the ORANI model (see the Foreword, by Alan Powell). The course is offered each summer on the campus of Purdue University and offers participants a hands-on introduction to the material in this book. Periodically, overseas versions of the course are also undertaken. Current developments in the GTAP data base and recent applications are explored and each participant has the experience of replicating/extending one such application during the course.

Overview of the book

This book is divided into four parts, of which this chapter is the first. Part II develops fundamental components of the GTAP data base and modeling framework. It begins with a thorough exposition of the standard GTAP model structure, including derivations and motivations as well as a complete listing of equations and variables. Chapters 3 and 4 cover the data and parameters in version 2 of the GTAP data base. All the applications in this book build on aggregations of this information. Chapter 5 discusses the method of aggregation. It also demonstrates how the theory, data, and parameters interact to determine *equilibrium elasticities* in the context of a 3x3 aggregation. Part II of the book concludes with Chapter 6, which describes how to access and use the *GTAP Book Version of GEMPACK*. It also contains an example of how to replicate results from an application in Part III. This chapter is accompanied by a "Hands-On" document, which may be obtained from the GTAP Web site.

Having covered the basics behind the GTAP, Part III of the book contains seven applications of the standard model. These are grouped by topic and examine issues such as: economic growth and trade, trade policy, resources, technology, and the environment. The first of these applications, Chapter 7, is authored by McDougall and Tyers; it focuses on the effects of economic growth on factor markets. In particular, they examine the impact that factor accumulation and increased openness in the rapidly developing economies (RDEs) of East Asia has had on factor markets in the older industrialized economies (OIEs). This represents a new, innovative use of applied general

equilibrium analysis. McDougall and Tyers find that growth and openness in the RDEs have indeed depressed the demand for unskilled labor in the OIEs, but the effect is quite modest. This leads the authors to side with those arguing that the significant decline in relative wages for the unskilled in recent decades is more likely due to biased technical change in the OIEs themselves.

The next three applications, Chapters 8–10, address various dimensions of trade policy liberalization. This is more familiar turf for AGE modelers. In Chapter 8, MacLaren provides an *ex post* analysis of the Cairns Group strategies for negotiation in the Uruguay Round. In particular, he estimates the benefits, to selected member countries, from alternative unilateral agricultural liberalization scenarios. These are compared to their negotiating positions. He concludes that there is an empirical economic basis for the differing political stances that Australia and Canada adopted during the GATT negotiations.

Whereas the MacLaren application focuses on unilateral liberalization in agriculture, the Young–Huff application in Chapter 9 examines the impact of multiregion, across-the-board cuts in protection. In particular, the authors compare two alternative approaches to free trade in the Asia-Pacific region: preferential versus nonpreferential (MFN). The question of which approach to take is currently being debated among Asia-Pacific Economic Cooperation (APEC) members. Some commentators have argued that the customary approach of only reducing intraregional trade barriers is too limiting in the dynamic Asia-Pacific region. Young and Huff shed some light on this issue with a carefully constructed set of experiments that highlight the importance of reciprocity on the part of non-APEC members, when liberalization is conducted on an MFN basis. Without such reciprocity, they find that liberalization on an MFN basis shifts a significant share of the global benefits to non-APEC members.

The final trade policy liberalization application is that of Yongzheng, Martin, and Yanagishima, in Chapter 10. These authors exploit the recent addition to the GTAP data base of bilateral quota rents associated with the Multifibre Arrangement (MFA). They examine the implications of reforming the MFA – or not – in the context of the broader set of Uruguay Round reforms. Failure to relax this system of bilateral quotas in conjunction with the other elements of a Uruguay Round package results in quotas that become *even more binding*. That is, the associated rents increase. The authors find that reform of the MFA comprises a large part of the global welfare gains to be had from the full Uruguay Round package, and the interaction between these bilateral quotas with non-MFA reforms is significant.

The last three applications in Part III of the book are drawn from the rapidly growing body of AGE-based work relating to resources, technology, and the environment. In Chapter 11, Tsigas, Frisvold, and Kuhn use the GTAP framework to examine the implications of climate change for global patterns

of production, consumption, and trade. Their emphasis is on agriculture, which is one of the industries most affected by global changes in temperature and precipitation. They survey the scientific literature in this area and specify a set of crop-specific productivity shocks. Simulation of the GTAP model permits them to examine the consequences of the distribution of global food production, consumption, and welfare. They are also able to evaluate the sensitivity of their results to a key scientific uncertainty, namely the potential impact of CO₂ fertilization. The authors demonstrate that the latter effect is capable of ameliorating many of the adverse effects of climate change on global food production. However, significant regional shifts in production and welfare remain. Finally, the authors utilize the *partial equilibrium* (PE) closures available in GTAP in order to assess the likely degree of error in earlier PE studies of climate change.

In Chapter 12, Perroni and Wigle show how the standard GTAP model can be supplemented by a set of side calculations in order to permit the user to conduct a more complete analysis of environmental policies. Particular features of the problem that their results address include: the presence of abatement technologies, and the benefits of abatement. Their approach is innovative, drawing on more specialized modeling work they have published elsewhere. The beauty of this chapter is that it shows how to incorporate these very important issues into this standard modeling framework, thereby facilitating combined analyses of resources, trade policy, and the environment.

In the final application, Chapter 13, Frisvold offers a readily accessible analysis of the intersectoral, multiregion effects of technological change in agriculture, using the GTAP framework. The results are used to place in perspective the existing literature on this topic and to shed new light on the question of who gains and who loses from different patterns of innovation and adoption of new technologies. In particular, Frisvold shows how the benefits of technological change depend on: (1) the extent of international spillovers associated with this innovation; (2) the trade position of the innovating country; (3) the stage of production where the innovation occurs; and (4) the factor bias involved.

Part IV of the book offers an evaluation of the GTAP framework, including performance of the standard model and quality of the data base and parameters. It begins with an attempt to evaluate the model's performance in a "backcasting" exercise that focuses on changes in export shares in the Pacific Rim over the decade of the 1980s. This was a period of dramatic change for many East Asian economies. The Newly Industrialized Economies (NIEs) such as Korea and Taiwan shifted their exports from labor-intensive manufactures to knowledge-intensive products, as the "new NIEs" such as Thailand took over exports of the former items. Is GTAP capable of generating these types of changes, based solely on observed changes in factor endowments and population? This

is the question Gehlhar asks in Chapter 14. In so doing, he employs both the standard GTAP model, and a slightly modified variant that incorporates a distinction between raw labor and human capital. The latter is shown to improve significantly the predictive power of the model, and this leads him to recommend further development of the data base in this direction. Finally, Chapter 15 provides an overall evaluation of the effort to date, as well as some observations about the future course of global trade analysis using the GTAP framework.

Reader's guide

The appropriate strategy for tackling this book depends on the objectives of the reader. For those who wish to master all the material, the most efficient approach is to read it chronologically—beginning with the model structure, reading about the data base and parameters, accessing the software from the Web site, mastering the 3x3 example, pursuing the applications, and, finally, turning to an evaluation of the GTAP framework. However, many readers will open this book with a specific question in mind. This suggests an alternative approach.

A very natural way to become familiar with GTAP is through a particular application. For example, if you have a specific interest in assessing the impacts of technological change you might wish to begin with Chapter 13. Having read this chapter, you discover the importance of specifying the precise form of technological change under consideration: is it Hicks-neutral – or perhaps labor-augmenting? To understand how these concepts are implemented in the standard GTAP model, you need to backtrack to Chapter 2 and examine the section on producer behavior.

Frisvold's technological change application also highlights the importance of a country's initial trade position and the general equilibrium demand elasticities that face its producers. You might then undertake a selective overview of Chapters 3 and 4, on data and parameters. You might also want to review Chapter 5 in some detail, as it is crucial in understanding the origin and interpretation of the general equilibrium demand elasticities that Frisvold uses in his analysis.

At this point, the reader with an interest in technical change is in a position to replicate the results. Chapter 6 offers a guide to accessing and running the software that accompanies this book. Not only can you replicate the results in Chapter 13, you can also examine their sensitivity to the author's assumptions about parameters and closure of the model. For example, how is the regional distribution of benefits from technical change in a single region affected by increasing the size of the trade elasticities? What happens when some economies attempt to insulate producers from declining world prices?

It is also possible to use this aggregation as a starting point for an entirely different experiment, perhaps involving trade policy liberalization.

Whatever strategy you choose to pursue in reading this book, I hope you will find the combination of theory, data documentation, computing, and applications to be rewarding. We maintain a discussion list and a bibliography of GTAP-based applications to which you are invited to contribute. The discussion list offers a vehicle for GTAP users, worldwide, to communicate with one another. Because GTAP is an ongoing project, we hope you will share your reactions, feedback, and questions with us via electronic mail sent to: *GTAP@FTP.PURDUE.EDU*. You may also wish to join gtap-l, the mailing list for those interested in GTAP, by sending the one-line message "subscribe gtap-l Jean Doe" to: <listserv@vm.cc.purdue.edu>, where Jean Doe is replaced by your name. GTAP also has a Web site with up-to-date information at:

<http://www.agecon.purdue.edu/centers/gtap/>