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INTRODUCTION TO COMPUTABLE GENERAL EQUILIBRIUM MODELS

Computable general equilibrium (CGE) models are widely used by governmental organizations and academic institutions to analyze the economywide effects of events such as climate change, tax policies, and immigration. This book is a practical, how-to guide to CGE models that is suitable for use at the undergraduate college level. Its introductory level distinguishes it from other available books and articles on CGE models. The book provides intuitive and graphical explanations of the economic theory that underlies a CGE model and includes many examples and hands-on model exercises. It may be used in courses on economic principles, microeconomics, macroeconomics, public finance, environmental economics, and international trade and finance, because it shows students the role of theory in a realistic model of an economy. The book is also suitable for courses on general equilibrium models and research methods, and for professionals interested in learning how to use CGE models.

Mary E. Burfisher is a Distinguished Visiting Professor at the United States Naval Academy, Annapolis, Maryland. She has also served as a senior economist for the Economic Research Service of the U.S. Department of Agriculture in Washington, D.C. Dr. Burfisher is a consultant on computable general equilibrium models and agricultural policy for U.S. governmental agencies and international organizations. She is the author or editor of numerous monographs, books, and articles on international agricultural and trade policies. Dr. Burfisher was a Fellow of the Global Trade Analysis Project (GTAP) at Purdue University from 2003 to 2010 and received the Quality of Communication Award from the American Agricultural Economics Association. She earned her Ph.D. in economics from the University of Maryland.

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For my family

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About This Book

Objectives

This book will introduce you to computable general equilibrium (CGE) models. A CGE model is a powerful analytical tool that can help you to gain a better understanding of real-world economic issues. CGE models are a class of economic model that over the past twenty-five years has gained widespread use in the economics profession, particularly in government. Economists today are using these models to systematically analyze some of the most important policy challenges and economic "shocks" of the twenty-first century, including global climate change, the spread of human diseases, and international labor migration.

Since the early 1990s, prominent CGE models have been built and maintained at the U.S. International Trade Commission, the Economic Research Service of the U.S. Department of Agriculture, the World Bank, and other national agencies and international organizations to provide ongoing economic analytical capability. These models have come to play an important part worldwide in government policy decisions. For example, the models' predictions about prices, wages, and incomes factored heavily in the debate about the terms of the North American Free Trade Agreement, the Kyoto Protocol, and China's entrance into the World Trade Organization. CGE-based analyses have also helped the United States and other governments anticipate and design responses to substantial changes in the availability of key resources, ranging from petroleum to people.

CGE models are comprehensive because – whether they are detailed or very simplified – they describe all parts of an economy simultaneously and how these parts interact with each other. The models describe the efficiency-maximizing behavior of firms and the utility-maximizing behavior of consumers. Their decisions add up to the macroeconomic behavior of an economy, such as changes in gross domestic product (GDP), government tax revenue and spending, aggregate savings and investment, and the balance of

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Prologue Table 1. *Modeling and Data Resources Used in This Book*

Resource	Source
RunGTAP CGE model	Download from GTAP.org
GTAPAgg7-global database aggregation utility	Download from GTAP.org
U.S. 3x3 database	Create using GTAPAgg7

trade. As might be expected, such models can require large databases and they contain sophisticated model code. Yet despite their complexity, continuing advances in modeling software and database development are making CGE models increasingly accessible and intuitive. Minimizing the technical entry barriers to CGE modeling has freed economists to focus on the models' economic behavior and the economic insights that can be derived from their results. These innovations have also made CGE models an ideal laboratory in which economics students can learn to manipulate, observe, and deepen their knowledge of economic behavior.

This book is designed to provide a hands-on introduction to CGE models. You will draw on theory from microeconomics, macroeconomics, international trade and finance, public finance, and other areas of economics, as you observe how producers and consumers in the CGE model respond to various changes in market conditions that we refer to as "model experiments." The guided model exercises will show you how to build and use a demonstration CGE model to assess the economywide effects of such economic shocks as the elimination of agricultural subsidies, global elimination of trade barriers, labor immigration, and changes in a tax system. By the end of the book, you will have begun to develop your skills as both a producer and a consumer of professional CGE-based economic analysis.

The book introduces the CGE models and databases that are used by professional economists. We will study the key features of "standard" CGE models, which are static (single period), single- and multicountry models, with fixed national endowments of factors of production. Most textbook examples and model exercises use RunGTAP, a user-friendly, menu-driven interface (Horridge, 2001) of the GTAP (Global Trade Analysis Project) CGE model. RunGTAP may be downloaded at no charge from the GTAP Web site (Prologue Table 1). The GTAP CGE model is an open model developed by Hertel and Tsigas (1997) and is written in the GEMPACK software.

The GTAP project also maintains a global database that CGE modelers rely on as a data source for many types of CGE models. The database is built on data contributions from CGE modelers around the world, which GTAP then organizes and balances into a consistent, global database. The 7.0

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version of the database, used in this book, describes 113 countries or regions and 57 industries in 2004. Modelers may use GTAPAgg, a freeware program developed by Horridge (2008b) and available from the GTAP project, to aggregate the global database into smaller sets of regions and industries that are relevant for their research. In this book and in the model exercises, most examples use a small-dimension, two-region aggregation of the database that describes the United States and an aggregate rest-of-world region.

Organization

This book covers eight topics beginning with an introduction to CGE models (Chapter 1), their elements and structure (Chapter 2), and the data that underlie them (Chapter 3). Chapters 4–6 focus on the microeconomic underpinnings of CGE models. Chapter 4 describes final demand by households, government, and investors and the demand for imports and exports. Chapter 5 describes supply, focusing on the technology tree and the producer's cost-minimizing demand for intermediate and factor inputs. Chapter 6 covers additional aspects of factor markets, including factor mobility, factor endowment and productivity growth, factor substitutability, and factor employment assumptions. Trade topics, including theorems on the effects of endowment changes and world prices, are covered in Chapter 7. Chapter 8 explores public finance topics related to trade and domestic taxes.

Chapters 1–8 adhere to a common template, consisting of:

- Chapter text (e.g., "Introduction to Computable General Equilibrium Models")
- Text boxes
- Chapter summary
- Key terms (e.g., "stock" and "flow")
- Practice and review exercises
- Model exercise

Text boxes introduce examples of classic, innovative, and influential CGE-based economic analyses that relate to chapter topics. These summarized articles offer practical examples of how the concepts that you are learning about in the chapter are operationalized in CGE models. Practice and review exercises review and reinforce the central themes of the chapter.

Model exercises linked to each chapter provide step-by-step direction and guidance to help you to develop your modeling skills (Prologue Table 2). The modeling problems are general enough to be suitable for use with almost any standard CGE model, but their detailed instructions are compatible with RunGTAP. The first three model exercises guide you in creating a database, setting up your CGE model, and learning core modeling skills. You may use the demonstration model developed in the first model exercise

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Prologue Table 2. *Chapters and Related Model Exercises*

Chapter	Model Exercise
1. Introduction to CGE Models	Set up the GTAP Model and Database
2. Elements of a CGE Model	Explore the GTAP Model and Database
3. The CGE Model Database: A Social Accounting Matrix	Run the GTAP Model
4. Final Demand in a CGE Model	Soaring Food Prices and the U.S. Economy
5. Supply in a CGE Model	Food Fight – Agricultural Production Subsidies
6. Factors of Production in a CGE Model	How Immigration Can Raise Wages
7. Trade in a CGE Model	The Doha Development Agenda
8. Taxes in a CGE Model	The Marginal Welfare Burden of the U.S. Tax System
	Challenge: Successful Quitters: The Economic Effects of Growing Antismoking Attitudes

to replicate almost all results reported in the tables in Chapters 1–8 of the book. Exercises 4–8 are case studies that begin with a discussion of a timely topic or influential CGE analysis such as labor immigration and U.S. tax policies. They demonstrate how to design model experiments and how to use economic theory to select and interpret model results. A ninth "challenge exercise" introduces advanced students to macroprojections and uncertainty about economic shocks.

Resources for New CGE Modelers

We recommend that beginning modelers start by reading articles and monographs, both current and classic, that provide general introductions to, or critiques of, CGE models. Particularly recommended as introductory treatments are Piermartini and Teh (2005), McDaniel et al. (2008), Shoven and Whalley (1984), Bandara (1991), Francois and Reinert (1997), Robinson et al. (1999), Devarajan et al. (1990, 1997), and Borges (1986). Breisinger, Thomas, and Thurlow (2009); Reinert and Roland-Holst (1992); and King (1985) provide introductions to social accounting matrices, which are the databases that underlie CGE models.

As your skills progress, we recommend that you read the intermediate-level treatments in Kehoe and Kehoe's (1994) primer on CGE models and Dervis, de Melo, and Robinson's (1982) introduction to open economy CGE models. Hosoe, Gasawa, and Hashimoto (2010) introduce students at

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an intermediate level to CGE models, focusing on models coded in General Algebraic Modeling Software (GAMS). Some books and articles that describe specific CGE models are also useful for new modelers, who will recognize many of the same features in those models as in the standard CGE model that we study in this book. Hertel and Tsigas (1997) provide an overview of the GTAP model. Lofgren, Harris, and Robinson (2002) describe the International Food Policy Research Institute's (IFPRI) standard single-country CGE model and database. De Melo and Tarr (1992) describe the structure and behavior of their CGE model of the United States. For more advanced students, Shoven and Whalley (1992) provide a practical introduction to CGE models, and Scarf and Shoven (2008) present a collected volume of case studies that describe different aspects of CGE models.

Because CGE modeling is a dynamic field of research, the best way to keep abreast of developments in CGE modeling and in the applications of CGE models is to review working papers and conference papers, in addition to economic journals. The GTAP Web site, at www.gtap.org is a useful source for up-to-date information on CGE-based research papers, CGE model databases, and research tools and utilities related to the GTAP model and data. All papers presented at annual GTAP conferences are posted online, providing students with access to unpublished papers and work in progress by many leading CGE modelers, using many types of CGE models. Perusing recent conference papers can give you ideas for timely research topics and experiment designs for your own research projects.

The International Food Policy Research Institute (IFPRI), which developed the "IFPRI standard" CGE model, has published many studies based on variations of that model as well as papers about model databases and database construction. These publications are available from the IFPRI Web site at www.ifpri.org.

Many international organizations, such as the World Bank, and national government agencies, such as the U.S. Department of Agriculture, also produce and post CGE-based working papers and research products. In addition, the GAMS Web site, at www.gams.org maintains a library of simple CGE models that can be downloaded and run using the free demonstration versions of GAMS. Also, the United States Naval Academy hosts the Tools for Undergraduates "TUG-CGE" model (Thierfelder, 2009), a GAMS-based CGE model designed for undergraduate use.

For the Instructor

The book is designed for use in a one-semester class that is spent primarily doing hands-on model exercises and independent research, with the book used as background reading. The exercises are all fully portable. They are

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Prologue Table 3. *Recommended Sequences for Courses of Different Lengths*

Chapter	One Semester Course	6-Week Course	1-Week Course
1. Introduction to CGE Models	0.5 weeks	0.5 weeks	Omit
2. Elements of a CGE Model	1 week	0.5 weeks	0.25 day
3. CGE Model Data: Social Accounting Matrix	1 week	1 week	0.5 day
4. Demand in a CGE Model	1.5 weeks	0.5 weeks	0.5 day
5. Supply in a CGE Model	1.5 weeks	0.5 weeks	0.5 day
6. Factors of Production in a CGE Model	1 week	Optional	Omit
7. Trade in a CGE Model	1.0 weeks	0.5 weeks	0.5 day
8. Taxes in a CGE Model	1.5 weeks	0.5 weeks	0.75 day
Independent Research	6 weeks	2 weeks	2 days

designed to use free materials downloaded from the Internet so they are suitable for students to carry out in computer labs or on their personal computers. The ideal classroom setting is one that promotes student teamwork and ongoing discussion among students and teachers while students carry out model exercises.

The book can also be used in condensed courses, with our recommendations for selecting and paring materials described in Prologue Table 3. For courses of all lengths, we recommend a generous allotment of time for model exercises and independent research because students will then learn by doing. If the book is used as a supplementary hands-on resource for economic theory courses, such as macroeconomics or international trade, we suggest that the teacher cover Chapters 1–3 and their related model exercises and then assign only the chapter and exercise that is relevant to the course. Most teachers are likely to find that some or all of Chapter 8 on taxes is relevant because taxes are a policy lever that governments use to address many economic problems.

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