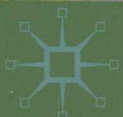
# Textbook of Computable General Equilibrium Modelling

## Programming and Simulations

Nobuhiro Hosoe,
Kenji Gasawa and
Hideo Hashimoto



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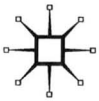

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# Abbreviations

## Abbreviations of general terms

| | |
|---|---|
| AGE | applied general equilibrium |
| ASEAN | Association of Southeast Asian Nations |
| CES | constant elasticity of substitution |
| CET | constant elasticity of transformation |
| CGE | computable general equilibrium |
| CSV | comma-separated value |
| EV | equivalent variation |
| GAMS | General Algebraic Modeling System |
| GAMS IDE | GAMS Integrated Development Environment |
| GATT | General Agreement on Tariffs and Trade |
| GDP | gross domestic product |
| GDX | GAMS Data Exchange |
| GTAP | Global Trade Analysis Project |
| IFPRI | International Food Policy Research Institute |
| IO | input–output |
| IRTS | increasing returns to scale |
| MDGs | millennium development goals |
| MFA | Multi-Fibre Arrangement |
| ROW | rest of the world |
| SAM | social accounting matrix |
| TOT | terms of trade |
| WTO | World Trade Organization |

## Abbreviations in social accounting matrices and GAMS input and output files

| | |
|---|---|
| AGR | agriculture |
| BRD | bread |
| CAP | capital |
| EXT | external |
| EPS | epsilon, i.e., a small value close to zero |
| EQU | equation |
| GOV | government |
| HOH | household |

| | |
|---|---|
| IDT | indirect tax |
| INF | infinity |
| INV | investment |
| JPN | Japan |
| LAB | labour |
| MAN | manufacturing |
| MLK | milk |
| SRV | service |
| TRF | tariff |
| USA | the United States |
| VAR | variable |

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# Symbols in CGE Models

### Symbols indicating indices

$i, j$: goods and firms (BRD, MLK),
$h, k$: factors (CAP, LAB),
$l$: households (HOH1, HOH2),
$r, rr$: regions (JPN, USA).

### Symbols in Chapter 2

[Endogenous variables]

$UU$: utility,
$X_i$: consumption of the i-th good,
$Z_j$: output of the j-th firm,
$F_{h,j}$: the h-th factor used by the j-th firm,
$p_i^x$: demand price of the i-th good,
$p_j^z$: supply price of the j-th good,
$p_h^f$: price of the h-th factor.

[Exogenous variables and constants]

$FF_h$: endowments of the h-th factor for the household,
$\alpha_i$: share coefficient for the i-th good consumption in the utility function,
$\beta_{h,j}$: share coefficient for the h-th factor used by the j-th firm in the production function,
$b_j$: scaling coefficient in the production function.

### Symbols in Chapter 6

[Endogenous variables]

$UU$: utility,
$Y_j$: composite factor, produced in the first stage and used in the second stage by the j-th firm,
$F_{h,j}$: the h-th factor used by the j-th firm in the first stage,
$X_{i,j}$: intermediate input of the i-th good used by the j-th firm,
$Z_j$: gross domestic output of the j-th firm,
$X_i^p$: household consumption of the i-th good,

$X_i^g$: government consumption of the i-th good,
$X_i^v$: demand for the i-th investment good,
$E_i$: exports of the i-th good,
$M_i$: imports of the i-th good,
$Q_i$: the i-th Armington composite good,
$D_i$: the i-th domestic good,
$p_j^y$: price of the j-th composite factor,
$p_h^f$: price of the h-th factor,
$p_j^z$: price of the j-th gross domestic output,
$p_i^e$: price of the i-th exported good,
$p_i^m$: price of the i-th imported good,
$p_i^q$: price of the i-th composite good,
$p_i^d$: price of the i-th domestic good,
$\varepsilon$: foreign exchange rate (domestic currency/foreign currency),
$S^p$: household savings,
$S^g$: government savings,
$T^d$: direct tax,
$T_j^z$: production tax on the j-th good,
$T_i^m$: import tariff on the i-th good.

[Exogenous variables and constants]

$FF_h$: endowments of the h-th factor for the household,
$p_i^{We}$: price of the i-th exported good in terms of foreign currency,
$p_i^{Wm}$: price of the i-th imported good in terms of foreign currency,
$S^f$: current account deficits in foreign currency terms (or equivalently foreign savings),
$\tau^d$: direct tax rate,
$\tau_j^z$: production tax rate on the j-th good,
$\tau_i^m$: import tariff rate on the i-th good,
$ax_{i,j}$: input requirement coefficient of the i-th intermediate input for a unit output of the j-th good,
$ay_j$: input requirement coefficient of the j-th composite good for a unit output of the j-th good,
$\alpha_i$: share coefficient for the i-th good consumption in the utility function,
$\beta_{h,j}$: share coefficient for the h-th factor used by the j-th firm in the composite factor production function,
$b_j$: scaling coefficient in the j-th composite factor production function,
$\mu_i$: share of the i-th good in government expenditure,

$\lambda_{ij}$: expenditure share of the i-th good in total investment,
$ss^p$: average propensity for savings by the household,
$ss^g$: average propensity for savings by the government,
$\gamma_i$: scaling coefficient in the i-th Armington composite good production function,
$\delta m_i, \delta d_i$: input share coefficients in the i-th Armington composite good production function,
$\eta_i$: parameter defined by the elasticity of substitution,
$\sigma_i$: elasticity of substitution in the i-th Armington composite good production function,
$\theta_i$: scaling coefficient in the i-th good transformation function,
$\xi e_i, \xi d_i$: share coefficients in the i-th good transformation function,
$\phi_i$: parameter defined by the elasticity of transformation,
$\psi_i$: elasticity of transformation in the i-th good transformation function.

**Symbols in Chapter 10 (selective)**

$SW$: social welfare,
$RT_i$: monopoly or quota rents in the i-th sector,
$\chi_i$: quota rent rate in the i-th sector,
$M_i^{quota}$: quota ceiling on the i-th good imports,
$FC_j$: fixed production costs of the j-th firm,
$v_j$: the share of the fixed cost payment to the household in total capital service payment by the j-th firm.

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# Preface

Computable general equilibrium (CGE) models are well grounded in standard microeconomic theory, where price is an important signal that drives agents in an economy. The modern economy cannot be examined without considering the role of the price mechanism. CGE models featuring the price mechanism are suitable for analysing contemporary policy issues in market economies and thus are used widely in various policy analyses, such as economic integration, global warming problems, tax reform, assistance for developing countries and so on. The potential of CGE models has encouraged many researchers and practitioners to cooperate in the development and use of these models; however, many of them have had difficulty in fully understanding CGE models, because of the complexity of the underlying economic theory, estimation techniques and computational requirements – this is why CGE models are sometimes called a 'black box'.

Despite the usefulness of CGE models, they have been used only infrequently in Japan. This is partly because, although many useful books and articles on CGE modelling are available in English, there were no comprehensive textbooks in Japanese, particularly for newcomers to CGE modelling. Therefore, we decided to write this textbook on CGE modelling in Japanese several years ago. Our endeavour resulted in the publication of *Textbook of Computable General Equilibrium Modeling – Programming and Simulations* by the University of Tokyo Press in 2004.

In the Japanese version of the textbook, we made considerable effort to help beginners to understand and build CGE models by themselves. The textbook was designed to be self-inclusive, proceeding in a step-by-step manner. We covered the A-to-Z of CGE modelling, starting from a basic setup of economic agents' behaviour, construction of databases, estimation of model parameters, computer programs and interpretation of simulation results. In each step, sample models with computer programs were presented.

The computer programs were written using the GAMS (General Algebraic Modeling System) software, whose trial version is publicly accessible on the GAMS web site free of charge. Assuming that most readers of this book were completely new to GAMS, we presented a detailed explanation of its use in the book. It was intended that, as readers become familiar with GAMS, they would be able to use the sample models on

the GAMS web site and to become acquainted with CGE models by experimenting with these sample models.

After the publication of our textbook in Japanese, we received requests from both international students studying in Japan and researchers in other countries to publish an English version. These requests motivated us to publish this book. In this English version, we retain the features of the Japanese version outlined above. At the same time, the English version is not a mere English translation. On the one hand, considerable effort has been made to improve the clarity of the explanation and to include recent changes to GAMS and data for CGE modelling. On the other hand, we omitted several sections that were specifically written for Japanese readers; in particular, actual examples of CGE analyses.

Partly because this textbook is written for beginners, and partly because of space limitations, this textbook covers only the basic features of CGE modelling. For example, we have not discussed dynamics or the monetary economy, which are discussed in other advanced books and journal articles about CGE models. After reading through this textbook, readers can start to explore such frontiers of CGE modelling. While we are confident that this book provides readers with all the essential knowledge and techniques of CGE modelling, we would appreciate any comments and suggestions that may improve this book.

We gratefully acknowledge useful comments and suggestions by Professors Kanemi Ban and Tatsuo Hatta, and by many friends, as well as readers of the Japanese version. In the publication of the Japanese version, we acknowledged Messrs Takuya Kuroda and Toshihiro Ikeda at the University of Tokyo Press for their assistance. We thank the University of Tokyo Press for providing permission to publish this English version. Regarding the software used for the modelling discussed in this book, we are indebted to Mr Alex Meeraus and his associates in GAMS Development Corporation for their generous support of our use of GAMS in both the Japanese and English versions of our book. The use of GAMS throughout this book allows us to provide a practical introduction to CGE modelling. We gratefully acknowledge the financial support of a Grant-in-Aid for Scientific Research (No. 20330053, 21730222) by the Ministry of Education, Culture, Sports, Science and Technology of Japan and the Japan Society for the Promotion of Science. We also acknowledge MIT Press and Elsevier for granting us permission to reprint certain figures originally contained in their publications, and Microsoft Corporation and GAMS Development Corporation for granting us permission to use screen shots of their products.

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