PART IV

EVALUATION OF GTAP

CHAPTER 14

Historical analysis of growth and trade patterns in the Pacific Rim: An evaluation of the GTAP framework

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I Introduction and overview

The product of many model building exercises is often seen as simply another economic model to add to a collection rather than the birth of an important tool capable of generating better information for answering economic questions. The concern that most modeling activity is conducted primarily for the benefit of the economic modeler has been expressed frequently (Dee 1994). Much attention is focused on modeling activity rather than on results generated from models. Are the results generated from applied general equilibrium models (AGE) to be taken seriously? This chapter argues that if results from AGE analyses are to gain greater credibility, further work on model validation is required.

There are many reasons for the current level of skepticism surrounding large-scale modeling efforts. In operationalizing such models, one is required to make many assumptions regarding the data base, behavioral equations, and parameters. This opens AGE-based research to widespread criticism. AGE modelers may find most of these assumptions to be necessary and defensible, yet this provides little assurance of results to consumers – especially those who are already skeptical of large-scale modeling. This author believes that evaluation of a model, solely via the scrutiny of its assumptions, is not a very useful exercise. Of more interest to consumers of AGE results is whether or not a model is capable of producing a proven set of results deemed accurate and reliable. This depends not only on the theoretical assumptions underlying the model, but also on the parameters, data base, and closure employed. Therefore, research aimed at evaluating models based on their predictive performance seems well placed. However, only a few such validation attempts have been made (Kehoe and Sancho 1991; Parmenter, Meagher, and Higgs 1993). The purpose of this chapter is to assess the predictive capability of the

Global Trade Analysis Project (GTAP) modeling framework by performing a "backcasting" exercise.

Despite widespread interest among AGE modelers in issues of computational methods, it is important to bear in mind that this validation exercise is not primarily related to the nature of the computational method employed [see Hertel, Horridge, and Pearson (1992) for a discussion of the latter issue]. In this exercise we seek to test for the economic truthfulness of results as opposed to the mathematical accuracy of solutions alone. Mathematical accuracy of a solution is a necessary, but not a sufficient, condition for obtaining meaningful economic results. Any synthesized data base and fictitious behavioral equations can be used to for testing solution accuracy but would be futile in testing for economic truthfulness.

By performing a "backcasting" exercise, we can evaluate the modeling framework, taken as a whole. If, for instance, the data are regarded as superior but the behavioral equations are poorly specified, the overall performance is likely to be poor. Similarly, good theory combined with poor data is unlikely to bear much empirical fruit. Nothing short of full-blown model simulation, compared with observed outcomes, can provide an assessment of the combined performance of theory data parameter and closure.

Backcasting is a common means of model validation. The advantage of this approach is that the exogenous variables upon which the AGE predictions are conditioned are known. This means that one can focus efforts on how well the model itself performs when compared to the historical record. Choosing an appropriate historical event for comparing model results is critical for this exercise. Since the GTAP model is based on standard, neoclassical theory, it makes sense to choose a backcasting challenge that this theory is capable of explaining. Some historical events are a direct result of rational economic behavior; however, noneconomic events can influence economic variables as well. Embargos, economic sanctions, and catastrophic events such as wars and natural disasters are examples of events not suitable for replication.

Since backcasting requires a complete profile of exogenous shocks and their endogenous consequences, it is difficult to apply this method to specific policy changes. It is often difficult to establish exactly when the policy was announced and when the effects fully materialized [see Kehoe and Sancho (1991) for an exception]. There is also the problem of disentangling these effects from those of other policies. Therefore, this chapter does not focus on policy shocks.

A more obvious economic event is that of growth and structural change in production, consumption, and trade. The fast growing East Asian countries provide the best examples of this type of economic shock. Growth-related changes tend to dominate all other changes for countries in this region, and this process appears to conform well with standard neoclassical growth theory

(Young 1994). It is this growth process for which we choose to perform a historical backcasting exercise of the GTAP model. Starting with the GTAP data base for 1992, a backcasting experiment is conducted whereby individual regions in the model are shocked such that the endowment levels are returned to their original, 1982 levels. The model adjusts to these new endowment levels such that all factor and output markets clear and a new equilibrium is found. The new equilibrium is postulated to depict the 1982 state of the world economy. The difference in export value shares from 1982 to 1992 are calculated and compared with historical changes in these shares in order to evaluate how well the standard GTAP model predicts the dramatic changes in trade composition over this period.

Because of the importance of human capital in the growth of East Asian economies, a modified model is also explored in this chapter. This modified model includes both raw labor and human capital as factors of production. As such, it represents a departure from the structure laid out in Chapter 2.

II Historical patterns of growth and trade in East Asia

Much attention has been given to the unprecedented growth that has occurred recently in East Asia. The economies of this region often are referred to collectively as the "growth center of the world." Unlike other parts of the world, these economies continued to grow through the oil crises of the 1970s and the world economic recession in the early 1980s. The dynamic structural changes that occurred in fast growing countries of East Asia have been clearly revealed through an analysis of input–output (IO) tables sponsored by the Institute of Developing Economies (IDE) in Tokyo (Furukawa and Inomata 1993). By making comparisons across different time periods using an international IO system, the dynamics of growth could be observed and analyzed. Specifically, this study examined the changes in bilateral trade, the extent to which developing countries are dependent on foreign inputs of capital goods, the destinations of final demands, and the changing structure of domestic production and trade. In the case of the East Asian developing countries, they relied heavily on foreign inputs for their manufacturing sectors, importing massive amounts of capital goods from the US, Japan, and Europe.

In general, standard trade and development theory (Chenery, Robinson, and Syrquin 1986) suggests that a poor country opening to trade tends to specialize in the export of primary products, although less so the more densely populated the country. If its domestic incomes grow more rapidly than the rest of its partners', production will gradually switch away from primary products to manufactures. The manufactured goods initially exported will be more labor-intensive the more resource-poor or densely populated the country. Since many textile and clothing production activities tend to be intensive in the use of unskilled labor, they would be among the items initially exported by a newly industrializing, densely populated country. In more developed countries where physical capital and human capital are relatively more abundant, real wages tend to be higher, shifting comparative advantage away from labor-intensive sectors. This is indeed the succession of economic activity that is observed among the East Asian countries.

Thailand provides a good example. Historically this country exported primary and agricultural products derived from its rich natural resources. However, as wage rates rose in the newly industrialized economies such as Korea and Taiwan, Thailand gained comparative advantage in light manufactures. The textile and clothing industry became particularly important during the 1980s. Indeed, exports of these products grew so rapidly during this period that they became the country's largest source of foreign exchange earnings. Both Indonesia and the Philippines experienced similar changes during this period. In Indonesia, the decline of world oil prices created strong pressures for structural adjustment in which the primary products sector shrank and light manufacturing grew rapidly.

These developments in Southeast Asia have been mirrored by changes in the more industrialized economies of Taiwan and Korea. The latter have shown declines in the exports of clothing and textiles, with large gains in machinery and equipment. Light manufacturing's share of exports has been rising in the lower-income developing countries, and falling in Korea and Taiwan. In Indonesia, the share of light manufactures was only 2.6% in 1982, but this rose sharply over the ensuing decade, reaching 22.5% in 1992. Throughout the late 1960s and 1970s, light manufactures share had been rising in Korea and Taiwan, but this took a sudden turn downward in the late 1970s. For Taiwan, the share of light manufactures dropped from 32.4% in 1982 to 22.1% in 1992; however, in Thailand the share increased from 11.4% in 1980 to 18.5% in 1992.

Other trends are common to all these East Asian economies. For example, they all expanded their share of machinery, vehicles, and equipment exports over this period. This sector, consisting mainly of differentiated, high-tech finished goods, has been rapidly expanding in the newly industrializing countries. It consisted of only 6.4% of Thailand exports in 1982, but in 1992 it rose to 23.9%. Conversely, agriculture's share of exports for all countries in this region fell during the 1980s. The relative decline in agriculture has traditionally been linked to demand-side factors; however, empirical evidence suggests that factor accumulation and the resulting supply-side pressures may also be important (Martin and Warr 1993; Gehlhar, Hertel, and Martin 1994). These same supply-side forces help explain the extraordinary growth of manufactures in East Asian countries. In addition to factor accumulation, some argue that it was these countries' outward orientation of trade policy, leading to scale economies and improved efficiencies, that generated rapid expansion in manufacturing exports.

What is the primary source of this growth, and can it be accurately represented in the GTAP model? Young (1994) provides compelling evidence on this issue by performing a detailed analysis of historical output growth, factor accumulation, and productivity growth. He concludes that neoclassical theory is well equipped to explain this growth. Specifically, he shows that the combination of factor accumulation, rising labor participation rates, new investment, higher education, and intersectoral transfers of labor out of agriculture to other sectors explain almost all of East Asia's growth in the last two decades. In light of Young's conclusions, it would seem that this provides an ideal situation for conducting a historical validation exercise using GTAP.

It is important to realize that for growth and structural change to occur, appropriate primary factor inputs must be supplied and a demand for output must also exist. Park (1993) summarizes the importance of human capital, stating:

> All the discussion about building of an export base, technological absorptive capacity as well as industrialization in general, seems to revolve around the role of one obvious but all-important factor, namely human capital. Cheap labor alone is not enough. What gives a country its competitive edge is the quality of its labor. Nothing matters more than education. In this regard, it must be recognized that what gives developing countries a potential edge is not cheap unskilled labor, but a skilled workforce, that is managers, professionals, engineers, technicians, scientists and even bureaucrats who are relatively cheap compared to those in developed countries. (p. 57)

For this reason we also explore a modification to the standard GTAP model and data base to break out of human capital as a separate factor of production, thereby enhancing the model's ability to predict the historical changes in trade patterns.

III Aggregation of sectors and countries

For purposes of this validation exercise, the 37 GTAP sectors were aggregated into 10 sectors based on similarities in factor shares and similarities of sectoral characteristics (see Table 14.1 for a complete listing of sectors used in this aggregation). Agriculture (AGR) consists of paddy rice, wheat, other grains, nongrain crops, wool, and other livestock. Processed agricultural sectors (PAG) consist of processed rice, meat products, milk products, other food products and beverages, and tobacco. Although processed agriculture does not have to compete for land, its growth is heavily dependent on growth of domestic agriculture, which comprises a large share of intermediate inputs. The other

Table 14.1. *Industry/Commodity Grouping*

Aggregate Groups	Original GTAP Industries
1. Agriculture (AGR)	
	Paddy rice Nongrain crops Wheat Grains, other than wheat & rice Wool Other livestock products
2. Processed agriculture (PAG)	Fisheries Processed rice Meat products Milk products Other processed food Beverages and tobacco
3. Fuels and minerals (FMN)	Coal Oil Gas Petroleum and coal products Other minerals
4. Clothing and textiles (CTX)	Textiles Wearing apparel
5. Other light manufactures (OLT)	Leather goods Lumber and products Pulp paper Paper and printing Other manufacturing
6. Chemicals (CHM)	Chemicals, rubber, and plastic products
7. Machinery-equipment-vehicles (MEV)	Transport equipment Machinery and equipment
8. Basic manufactures (BAM)	Primary iron and steel Nonferrous metals Fabricated metal products
9. Nontraded services (NSV)	Electricity, gas and water Construction Ownership of dwellings
10. Traded services (TSV)	Trade and transport Other services (private) Other services (government)

primary goods sector is fuels and minerals (FMN), which consists of coal, oil, gas, other minerals, and petroleum and coal products.

From the 14 GTAP manufacturing sectors, 5 aggregates were created. These sectors include clothing and textiles (CTX), other light manufactures (OLT), chemicals (CHM), machinery equipment and vehicles (MEV), and basic manufactures (BAM). Of the 6 GTAP service sectors, 2 aggregates were

Table 14.2. ***Shocks Used in the Backcasting: Cumulative (reversed) Growth, 1992—1982. (% changes)***

Regions	Population (1)	Labor Force (2)	Human Capital (3)	Physical Capital (4)
US & Canada	-9.03	-10.87	-37.64	-24.60
EU	-3.07	-8.06	-34.98	-23.20
Japan	-4.82	-7.84	-41.66	-41.66
Korea	-10.77	-20.82	-67.20	-66.17
Taiwan	-11.38	-21.10	-61.20	-54.09
Malaysia	-21.51	-24.10	-73.04	-54.66
Thailand	-15.02	-16.05	-73.18	-56.18
Indonesia	-17.25	-21.56	-67.57	-59.14
Philippines	-20.21	-21.13	-48.31	-28.95
ROW	-17.70	-17.70	-26.00	-26.01

Sources: Columns 1 and 2: Urban and Nightingale (1993); column 3: Nehru, Swanson, and Dubey (1993); column 4: Nehru and Dhareshwar (1993).

created. These include nontraded (i.e., lightly traded) services (NSV) and traded services (TSV).

Individual countries have grown at different rates, and relative factor proportions have varied across countries. Therefore, the regional aggregation scheme has identified seven *individual* East Asian countries and three regional aggregates. The countries and regions are listed in Table 14.2. Evaluation of results will focus on the six rapidly growing countries in East Asia, where growth-related changes in trade patterns are most obvious. These countries include South Korea, Taiwan, Malaysia, Thailand, Indonesia, and the Philippines. Changes in the composition of export shares are analyzed for these individual countries from 1982 to 1992.

IV Modifying the standard GTAP model

In this analysis, an alternative variant of the standard model is also used to shed additional light on directions for improvement of the standard model. This involves a slight alteration in the model's production structure and data base. The standard GTAP model contains only three primary factors of production (agricultural land, labor, and capital). For reasons given above, it is believed that disaggregation of the labor input is important. In fact, some users of the GTAP model/data base have already made such alterations and have found it quite important for their specific applications (McDougall and Tyers 1994; Zhi 1994). Likewise, for this particular application, where attention is focused on sectoral growth and trade, it is also believed that multiple labor types is a critical factor influencing the outcome of a growth shock. To do a thorough job incorporating such information in a multicountry/sector model is a daunting task given the enormous data requirements. As of now, the task is not fully completed. Nevertheless, with the available data one can make a fairly reasonable first cut at the problem.

Labor is broken into two components: human capital and raw labor. Human capital is distinguished from raw labor because of its capability in generating nonrepetitive activity such as strategic decision making, conceptualizing new ideas, and generation of knowledge. Such activity cannot be replicated by nonhuman factors of production, namely physical capital. Raw labor, however, is capable of generating only recurrent or repetitive activity, which technically can be replicated by nonhuman factors of production. This description of human capital follows closely that of Romer (1990). It is the key input to research and development, generating new ideas and products. Countries with greater human capital stocks are capable of introducing more new products, which in turn helps foster growth. Sound empirical evidence shows the importance of human capital and its contribution to growth in cross-country studies (Barro 1991). Individual sectors have different input requirements for human capital, and this factor input adds a new dimension to sectoral differentiation in the model. For example, high-tech or knowledge-intensive manufacturing requires a greater share of human capital than does the assembly of wearing apparel.

Implementation of this particular modification in the standard GTAP model requires an appropriate behavioral specification in the production structure and an appropriate labor payment split between raw labor and human capital. Here it is assumed that human capital and physical capital are complementary inputs (Griliches 1969; Fallon and Layard 1975; Rice 1989). Specifically, these two inputs are nested at the bottom of the CES production function with very limited substitutability ($\sigma = 0.1$). Labor and composite capital (physical and human capital) are substituted in the same manner as in the standard model. This alternative specification is easily implemented via modification of the standard GTAP model. The stock of human capital for individual countries is adopted from Nehru, Swanson, and Dubey (1993), where human capital is measured as an educational stock embodied in the labor force. Since human capital is, by definition, capable of generating critical knowledge and ideas, the stock of tertiary education is the most appropriate proxy for this input. This is believed to be particularly useful in gauging a country's level of development and changes in the stock of its talented professionals.[1] The latter are critical for growth analyses.

In order to split labor payments in the GTAP model, we would ideally like to have data on educational levels and occupation, wage rates, and sector of employment for all labor force participants in the world at a single point in time. Since such data are unavailable, compromises were necessary. In particular, those countries with available data were used as representative members of three types of countries: industrialized, newly industrialized, and developing countries.[2] Data from the US served as representative of industrialized countries. For the US, information on occupational employment by industry and wages and salaries was used to establish the labor shares, by sector. Payments to human capital consist of payments to professionals, paraprofessionals, and technical workers. As stated by the Occupational Employment Statistics Survey, this group of individuals requires substantial educational preparation at the university and postgraduate levels. The largest concentration of this group was found in electrical equipment and machines and transportation equipment industries. Given the high level of product innovations and research and development activity required in these industries, it is not surprising that this sector requires a high share of well-trained individuals. Similar data was also available for Hong Kong (newly industrialized) and China (developing).

Having established employment shares for developed countries, newly industrializing countries, and developing countries, we combined this information with country-specific wage data to convert quantity shares into value shares for countries other than the representative regions. On *value share* basis, machinery, equipment, and vehicles (MEV) is consistently more knowledge-intensive or human capital–intensive than other manufacturing sectors, and clothing and textiles (CLT) is consistently more labor-intensive than all other manufacturing sectors.

V Experimental design

The objective of this chapter is to determine to what extent the past is reproducible by the GTAP model. Specifically, can GTAP reproduce the trade patterns as they appeared in 1982, using the 1992 data base as a starting point? Because GTAP is not a growth model, it cannot endogenously determine changes in physical capital, labor force, population, or total factor productivity over time. Therefore, estimates of all relevant growth statistics must be obtained outside the GTAP framework. In particular, four variables must be shocked in this backcasting exercise: population, labor force, human capital, and physical capital. The associated shocks for each country/region over the 1992–1982 period are shown in Table 14.2. Two important assumptions are made in this experiment. First, land is assumed to be in fixed supply between 1982 and 1992. Second, the *ad valorem* equivalent level of policy interventions is left unchanged. That is, lacking further information, we are forced to assume that policy changes produced negligible effects in trade patterns during this period of time.

All regions in the world must be shocked by their corresponding endowment change for the time period. Therefore, it is important to obtain cross-country growth–based rates on the same methodology and definitions. This helps to avoid the problem of obtaining inconsistent or biased growth statistics. (Growth statistics obtained from various single-country studies employing different methodologies would be clearly inappropriate.)

The term "physical capital" is taken in this study to refer to goods that are fixed, tangible, durable, and reproducible. This definition is consistent with the UN classification of gross fixed capital formation. It rules out a country's financial assets (because they are intangible) and natural resources (which are nonreproducible). The estimates of changes in physical capital stocks between 1982 and 1992 were taken from Nehru and Dhareshwar (1993) for all countries in the model. The shocks to human capital were taken from the estimates made by Nehru, Swanson, and Dubey (1993). Specifically, this is a measure of the change in education stock contained in the labor force for individual countries. Shocks for population and labor force were obtained from Urban and Nightingale (1993). Changes in population are directly related to changes in labor force, but differences exist due to demographic changes.

Four experiments are conducted in this exercise. The first (E1a) is a growth experiment with the standard GTAP data base and model with all parameters set at their original values. The second (E1b) is conducted with the standard data base and model, but with the trade elasticities raised by 20% of their original values. This tests the hypothesis that the current Armington elasticities are too small for a 10-year simulation and therefore restrict the trade pattern changes. The third experiment (E2a) uses a data base that breaks out the human capital component in labor. As noted above, human capital is believed to be a factor input that is important in the growth of sophisticated manufactures. Finally, the forth experiment (E2b) uses the combination of both the labor split and the larger trade elasticities.

VI Results

The top entries in Table 14.3 (all countries), provide a summary constructed by pooling the results produced from the backcasting exercise for all countries. Because there are 6 individual countries and 7 sectors used in this analysis, there are a total of 42 observations for each experiment. These are used to calculate the statistics found in Table 14.3. Each observation is an export share change calculated by taking the difference between the 1992 value and the 1982 value. Of importance for this analysis is the extent to which the predicted changes produced from the GTAP model correspond to the actual changes that took place in history. We examine two measures of the strength of the relationship between the predicted and actual results. The first is the coefficient of simple correlation. This provides an indication of how well the GTAP model tracks the *direction* of historical change, and is reported in the first pair of columns in Table 14.3. The closer the statistic comes to 1.0, the stronger the correlation is between actual

Table 14.3. ***Relationship Between Predicted and Actual Changes in Export Shares***

	Correlation		Slope	
Country	Exa[a]	Exb[b]	Exa	Exb
All Countries				
1[c]	.71	.72	.18	.21
2[d]	.77	.78	.48	.55
Thailand				
1[c]	.87	.88	.14	.14
2[d]	.95	.96	.83	.94
Malaysia				
1[c]	.95	.95	.18	.21
2[d]	.97	.97	.85	.95
Philippines				
1[c]	.95	.95	.23	.27
1[d]	.78	.80	.31	.37
Indonesia				
1[c]	.66	.68	.19	.22
1[d]	.64	.65	.13	.15
Korea				
1[c]	.48	.54	.30	.54
1[d]	.85	.85	.32	.36
Taiwan				
1[c]	.85	.82	.13	.14
1[d]	.83	.84	.16	.17

[a] The results in this column refer to experiments using the standard trade elasticities.
[b] The results in this column refer to results based on increased trade elasticities.
[c] The results in this row are based on the standard GTAP model.
[d] The results in this row are based on the human capital-augmented model.

and predicted changes. Overall the model performs fairly well in this regard. Of the four experiments, 2b shows the highest correlation of 0.78. This suggests that by adopting a labor split with human capital as a component (experiments 2a and 2b), overall results improve. There is also some indication of a small improvement in the correlation results by increasing the trade elasticities in the GTAP model (experiments 1b and 2b).

The measure of responsiveness of model results, relative to actual changes, is summarized in the slope coefficient reported in the second column of Table 14.3. It represents the coefficient when model predictions are regressed on actual changes. An estimated value of 1 indicates that the magnitude of change in the predicted and actual change is equal. This is an ideal outcome. However, all the slope parameters are less than 1, indicating that the actual changes are consistently greater than the predicted changes. That is, the model is *underpredicting* changes in export shares in East Asia over this period. Like the correlation statistic, there is an improvement, as reported over all countries, by increasing the trade elasticities or making a labor split in the data base. For the standard model, the results appear quite unsatisfactory. The predicted changes are significantly lower than the actual changes, as indicated by the very low slope parameter.

The next part of Table 14.3 displays statistics of the four experiments on a country-by-country basis. This table is helpful for evaluating each individual country's performance in the backcasting experiment. Although the results vary across countries, evidence suggests that the modified version of the model does improve predictive capability. Predictions for some of the Association of South East Asian Nations (ASEAN) countries that were known to have inherent stability in their historical growth patterns performed modifications. Of these, Malaysia and Thailand showed most improvement using the alternative model specification. For Thailand the slope coefficient was 0.14 using the standard model, but it increased to 0.94 using the modified model in conjunction with the increased trade elasticities. Malaysia showed similar improvements in this regard. Korea, Taiwan, and the Philippines also showed some signs of improvement over the standard model predictions either in terms of the slope or correlation coefficients.

Since Indonesia underwent the most radical structural change of any of the countries over this period, it is not surprising that the results are relatively poor. During the period 1982–1992 there was a sudden surge in Indonesian exports of light manufactures, textiles, and wearing apparel that the GTAP model was unable to predict given the very small base it started with in the early 1980s. Many other factors besides factor accumulation contributed to Indonesia's rapid structural change during this period, including a rapid deterioration in oil prices, which is not built into the exogenous shocks to the model.

Overall, the above results suggest that the standard GTAP model has some information content that is relevant to the East Asian experience. This is indicated by the correctness in the *direction of change* of the predicted shares. But the results also point out that the model is missing important economic information pertinent to the evolution of Pacific trade over the 1980s. The sharp improvements in the results generated by the modified version of the GTAP model suggest that separating labor into two components should be a high priority in future work.

VII Conclusions

This chapter made three distinct contributions. First, it provided a basic methodology for performing validation exercises with the GTAP model. Second, based on this validation effort, it identified some deficiencies in the standard GTAP model. Third, it tested an extension of the standard model and suggested directions for future improvements in the framework.

Economists will always have to make assumptions in the model-building process, and in doing so they will inevitably face criticism of their decisions. However, it is impossible to evaluate the quality of an empirical model, based solely on its assumptions. In particular, one cannot distinguish the "bad" assumptions from the "not so bad" ones because of the difficulty in determining the effects of the assumptions on the overall results. In this chapter new assumptions were added to an existing model. Like any others, these assumptions are fair game for criticism. The key point is that these new assumptions were evaluated in light of the predictions from the two alternative models. In this case, evidence was produced showing that the new assumptions were indeed beneficial.

Specifically it was shown that by breaking labor into two components–raw labor and human capital–and assuming that capital and human capital are complementary inputs, significantly better predictions in East Asian export share changes could be obtained. It is a fact that human capital accumulation has been an important component in the industrialization of the fast growing East Asian economies. Some sectors are more dependent on this input than others. It is this very information that is missing from the standard GTAP model. However, it cannot be said that the newly created labor share splits are factual themselves. This is because comparable data were not obtained for all countries in the world. This can be rightly criticized. Nevertheless, its addition did result in improved model performance. I believe that the AGE field would benefit significantly from more of this type of model enhancing (as opposed to model building) activity, in conjunction with well-defined validation exercises.

NOTES

1. This should not suggest that all professionals necessarily make a contribution to growth but that human capital critical for growth is primarily concentrated among professionals within the labor force. Evidence exists suggesting that countries with a higher proportion of engineering college majors grow faster and are strongly positively correlated with investment in physical and human capital, but countries with a higher proportion of law graduates grow more slowly (Murphy, Shleifer, and Vishny 1991).
2. The method and data sources were adopted from Zhi, 1994. Sources include the "U.S. Occupational Employment Statistics Survey (OES) 1990," "Yearbook of Labor Statistics 1992," published International Labor Office, Geneva, and "Hong

Kong 1991 Employment in Manufacturing and other Industries by Major Occupational Group" published by Hong Kong Population Census 1991.

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CHAPTER 15

Implications for Global Trade Analysis

Thomas W. Hertel

A decade ago, John Whalley (1986) assessed the state of play in applied general equilibrium (AGE) analysis and summarized his findings in a chapter entitled "Hidden Challenges in Recent Applied General Equilibrium Exercises." At the time, he observed considerable frustration among AGE modelers with the seeming

> necessity to be a jack of all trades. When involved in modelling activity in the applied general equilibrium area, one has to be familiar with general equilibrium theory, to be able to program, to be familiar with data and be able to manipulate and convert it into a model admissible form, to be conversant with literature estimates of key parameters, to have a clear sense of policy issues and institutional structure, and to be able to interpret results. When confronted with this range of activities, it is perhaps not surprising that it becomes difficult for graduate students and others to enter this area." (pp. 38–39)

Although the advent of special purpose programming languages such as GAMS-MPS and GEMPACK have lessened the demands for programming skills, the other problems remain pertinent today. Indeed, with ever greater emphasis on global modeling, data problems have become only more severe.

Whalley goes on to discuss the value of *teams* of researchers, patterned after work in the natural sciences. This is the approach taken by the Impact Project, described in the foreword to this book. It is also the niche that the Global Trade Analysis Project (GTAP) has begun to fill in global trade analysis. By providing a standard data base and modeling framework, it has become possible for economists who are not specialists in AGE modeling to contemplate using the tool to address specific issues of interest without having first to invest an inordinate amount of time in data work and programming. A number of the applications in this book were developed by individuals in precisely these circumstances. Some authors may choose to work further on these questions to improve their analysis in terms of data, parameters, and economic behavior. This process will serve as a *hidden hand* feeding back these improvements and new ideas to GTAP, allowing others to capitalize on them. I believe that this type of cross-fertilization is extremely important to the long-run vitality and credibility of AGE analysis. These individuals also bring new applications ideas. As the software and data base continue to improve, I expect many more examples of this type of cross-fertilization based on GTAP.

Synopsis

The purpose of this book has been twofold. The first objective was a relatively straightforward one, namely, to document the GTAP framework, including model structure, as well as sources and procedures for constructing the data base and the parameter file. The second objective has been more challenging: to make available to readers a set of significant GTAP applications, along with the tools necessary to replicate them (and explore their sensitivity to key assumptions). As noted by Alan Powell in his foreword, replication is an essential, although oft-neglected, ingredient of empirical economic research. It is one of the best ways to learn about AGE modeling, and a fundamental part of this book.

However, making such applications available for easy replication is no small task. It has required many hours of graduate student time, as well as the expertise of the authors of the software and model. This effort has also benefited greatly from the existence of a "standard model" and a standard set of procedures for implementing applications. Indeed, based on this experience, we have developed a set of guidelines that should greatly facilitate the documentation and replication of future GTAP applications.

Of course, one danger of such an effort is that the standard model will become a straightjacket, unnecessarily limiting applications to what is feasible rather than what is most appropriate. In light of this concern, I am pleased with the diversity and quality of applications that appear in Part III. The Perroni and Wigle application of GTAP to analyze environmental policy offers an excellent example of how the standard model can be adapted to shed light on an important issue. In their case, a few outside calculations are required. However, this is far easier than building a new model from scratch. It can be followed up with further modeling work if deemed necessary.

This brings up an important point. Although the authors of the applications in Part III were required to adhere to the standard model structure, other users need not face this same restriction. Indeed, for those with access to GEMPACK, it is quite straightforward to modify selected equations, as needed, for other applications. Also, since the authors of such modifications have to present only their *changes* to the standard model structure, it is relatively easy to document such work. This frees up more of the methodologically oriented researcher's time for careful attention to the nature of the extensions being undertaken.

Finally, for experienced AGE modelers, with their own, preferred modeling framework, the data base itself will be of greatest interest. It can provide the starting point for applications using different models [e.g., models of trade with imperfect competition; see Francois, McDonald, and Nordstrom (1994); Hertel and Lanclos (1994); Harrison, Rutherford, and Tarr (1995)], or implementations of similar models in different software environments (Lewis, Robinson, and Wang 1995).

Evaluation and future directions

How does one evaluate an effort such as GTAP? There are several dimensions to this question. One of the main criteria for evaluating the success of AGE-based research efforts in the past has been their ability to generate insights into problems that are too complex to be addressed analytically. In Chapter 7, McDougall and Tyers emphasized the competing nature of income and substitution effects associated with developing country expansion and its impact on relative wages in industrialized economies. Although theoretical outcomes are ambiguous, the evidence they present suggests that the likely empirical effect of this expansion on real wages is positive, but relatively small.

In their chapter on climate change and agriculture, Tsigas, Frisvold, and Kuhn also generate some valuable insights into two, fundamentally empirical, issues. First, because past studies of this problem have been partial equilibrium (PE) in nature, the authors exploit PE closure options in GTAP to obtain estimates of the likely magnitude of the errors in these earlier studies. They find them to be substantial, particularly when only the primary food system is taken into account. Their second insight pertains to the relative importance of carbon fertilization in estimates of the effects on the global food system stemming from a doubling of atmospheric CO_2. Omitting this aspect of the problem vastly overstates the adverse consequences of this particular form of climate change for global agriculture. With carbon fertilization effects in place, only two regions experience welfare declines, and global welfare actually rises. Without these effects, all regions lose and the global welfare cost is substantial. This application is also an example of how GTAP may be used to prioritize future research (e.g., obtaining accurate estimates of the CO_2 fertilization effect is a high priority).

One of the features that distinguishes many GTAP applications is the emphasis on *experimental design*, which is considered only as an afterthought to many AGE studies. Appropriate experimental design can itself be the source of valuable insights. Whereas most analyses have simply focused on the impact of eliminating the Multifibre Arrangement (MFA), Yang, Martin, and Yanagishima evaluate its interaction with other trade policy instruments. They also show that elimination of the MFA *following* non-MFA Uruguay Round reforms has a stronger effect, because of the tendency of the latter reforms to exacerbate the effect of these bilateral quotas on textiles and wearing apparel.

Experimental design also plays an important role in the Young–Huff chapter on Asia-Pacific Economic Cooperation (APEC) liberalization. Rather than simply examining the impact of a specific type of APEC agreement, those authors choose instead to focus on the *difference* between two alternative strategies for Asia-Pacific free trade. In the first case, liberalization is conducted on a preferential basis. In the second, APEC regions lower trade barriers facing imports from *all* sources. This is currently a topic of heated debate within APEC and the results of these simulations show that a preferential agreement is more attractive for APEC members, unless most favored nation cuts are reciprocated by non-APEC regions.

In some cases the application does not focus on the experimental design issue, but the questions asked, and the comparisons made, may still be new. This is the case with Donald MacLaren's chapter, in which he conducts a series of experiments that have been run many times by others in the context of the Uruguay Round–namely unilateral liberalization of agricultural policies in some of the major exporting regions. However, to date, no one has attempted a serious comparison between what the models have predicted and the negotiating positions of individual countries. This is what makes MacLaren's evaluation of the Cairns Group strategies for agriculture such refreshing reading.

Of course, there are other cases in which we need a general equilibrium model to remind ourselves of something we may already have known, and to demonstrate its importance in the application at hand. George Frisvold's analysis of technological change in agriculture offers a good illustration of this point. There, he shows how the distribution of gains from research depend importantly on the own-price elasticity of demand for the product in question. In the case of agricultural products, which are heavily traded, this depends importantly on the share of the output exported and the relative importance of the innovating country in world output. The GTAP framework offers a consistent vehicle for providing comparisons of these equilibrium elasticities and sorting out their implications for the incidence of technological innovation.

I believe there is considerably more room for interplay between analytical and empirical work based on GTAP. Yang, Martin, and Yanagishima provide an example of how such work might proceed. In their analysis, they find that some of the MFA exporters lose from liberalization of that policy, while others gain. How can one explain this diversity of outcomes? In the appendix to their chapter, these authors show how the local change in welfare for the

MFA exporters may be decomposed into several components. This expression clearly shows that regions with high shares of sales to the restricted market are more likely to lose. That is indeed the case in their results. Future work along these lines could provide a numerical decomposition of the sources of welfare changes. This would go a long way toward increasing the attractiveness of AGE-based studies to other economists.

In the end, the quality of all the insights generated by GTAP hinge critically on the validity of the modeling framework itself. In Chapter 14, Gehlhar points out that this involves a simultaneous test of model, data, parameters, and closure. His effort to validate the GTAP framework by backcasting export shares for East Asian economies over the 1980s represents a pathbreaking attempt to address a major source of criticism of AGE analysis. By choosing an endowment-based shock, he has highlighted the importance of factor intensities in the model. His results show that the standard model lacks sufficient factor detail to reflect accurately these historical changes. When he adds human capital, the predictive performance for these dynamic economies is vastly improved. Gehlhar's work is a good example of how one can take advantage of an existing framework, judiciously building on it in order to address an issue. His research has also put factor intensity information high on the list of priorities for future GTAP data base work. Gehlhar's work also provides a natural lead-in to a discussion of future directions for the GTAP data base.

Data base

The GTAP data base has proven to be a tremendous resource for AGE researchers. This strong demand is continually demonstrated by the willingness of cash-strapped researchers to purchase it. The uniqueness of this data base is also one of the main reasons that various national and international agencies have stepped forward to join the GTAP Consortium and Advisory Board. There is simply no other publicly available data base that combines bilateral flows and input–output relationships in a microconsistent fashion. The involvement of these agencies will assure the continuity and continued improvement of this data base.

Future data developments will be motivated by the character of applications being demanded. As noted above, interest in growth and trade applications will lead naturally to an upgrade of the factor shares. Similarly, the demand for applications related to European integration is leading to improved coverage of that part of the world in future releases of the data base. Of course, this work must also consider the constraints on availability of secondary data. For this reason, it will be some time before improved coverage of some of the poorest developing countries is possible.

Most of the effort to date has been expended on assembling a globally consistent set of value flows for the GTAP data base. However, in the future, more attention will need to be paid to the behavioral parameters. Given the uncertainty associated with these elasticities, it is important to incorporate information on their *distributions*, as opposed to a single-point estimate. This will open the way to standardized sensitivity analysis, permitting users to place a confidence interval around estimates of particular interest. Current work using Gaussian Quadrature–based procedures (Preckel and Liu 1994) appears quite promising, as it offers a means of greatly economizing on the number of simulations required to provide a full-blown sensitivity analysis.

Conclusions

The data base is an essential input into GTAP; however, in the long run the most important resource will be the emerging *network of researchers* using the GTAP framework. Contributions from individuals in the network have comprised important ingredients in the annual data updates. These individuals have also played an important role in raising the visibility of GTAP within their respective national and international agencies. To date, most (although not all) of these members of the GTAP network have been participants in one of the annual short courses. It is hoped that publication of this book, combined with the Internet release of the associated software and data, will facilitate a broadening of this network. Consider this your invitation to participate!

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Glossary of GTAP notation

Padma Swaminathan

I Overview

Specification of the GTAP data base and model requires a vast amount of notation. This notation has been carefully chosen to be brief, yet descriptive. This glossary refers to variables used throughout this book. It also corresponds to the GEMPACK representation of the standard GTAP model, GTAP94.TAB, as specified in version 2, April 1995. It lists the sets and subsets, base data, derivatives of the base data, and variables used in the model. We hope that the glossary will be useful for both new and experienced users of the GTAP framework. Some important naming conventions follow.

1. Sets and parameters are denoted in uppercase.
2. The *levels* form of variables in the GTAP are denoted in uppercase. Percentage changes in variables are denoted in lower case (*linearized* form of variables). For instance, *PM(i,r)* is the market price of commodity *i* in *r* in levels form, and *pm(i,r)* = [*d PM(i,r)* / *PM(i,r)*]*100 % is the linearized form of this variable.
3. The GTAP data base comprises only value flows (in their levels form). Data base variables are accordingly written in uppercase. These are declared as *coefficients* in the GEMPACK code and are *updated* using percentage changes in the component prices and quantities, after each step in the solution. The data base stores the minimal amount of information. No redundancies are permitted.
4. Derivatives of the data base variables are also in levels form. There are two types of derivatives: value flows and shares. The derivative variables naturally get updated following each update of the data base.
5. The GTAP model consists of a system of linearized equations with all variables appearing in percentage change form. GEMPACK solves

for percentage changes in (endogenous) prices and quantities, thereupon relinearizing the model and solving it once again.

6. Dummy variables to identify zeroes in the base data are always written in uppercase. By including these in the model we avoid reporting meaningless percentage changes in quantity indices corresponding to zero flows.
7. Slack variables appearing in the linearized accounting relationships of the model are always written in lowercase.
8. Percentage changes in some useful derivative variables of trade value flows and income are given different names than their levels counterparts. (GEMPACK is not case-sensitive, so they cannot have the same name.) Although the base data and all the derivatives are automatically updated, they must be called for in separate DISPLAY statements to be viewed. They must also be compared to the initial data base to obtain their percentage change. Therefore, it is handy to give them different names and declare them as percentage change variables. These variables are listed under section D.7.
9. The model also computes changes in regional equivalent variations and trade balances absolute changes in $US 1992 million. Therefore, these variables are written in uppercase.

II Glossary

A *Sets and Subsets*

1 *Sets*

REG	Regions
NSAV_COMM	Non-Savings Commodities
TRAD_COMM	Tradeable Commodities
DEMD_COMM	Demanded Commodities
PROD_COMM	Produced Commodities
ENDW_COMM	Endowment Commodities
ENDWS_COMM	Sluggish Endowment Commodities
ENDWM_COMM	Mobile Endowment Commodities
CGDS_COMM	Capital Goods Commodities ("cgds")
ENDWC_COMM	Capital Endowment Commodity ("capital")

2 *Subsets*

PROD_COMM	⊂ NSAV_COMM
DEMD_COMM	⊂ NSAV_COMM

CGDS_COMM	⊂ NSAV_COMM
ENDW_COMM	⊂ DEMD_COMM
TRAD_COMM	⊂ DEMD_COMM
TRAD_COMM	⊂ PROD_COMM
CGDS_COMM	⊂ PROD_COMM
ENDWS_COMM	⊂ ENDW_COMM
ENDWM_COMM	⊂ ENDW_COMM
ENDWC_COMM	⊂ NSAV_COMM

Example: The 3x3 Economy

REG	= {usa, e_u, row}
NSAV_COMM	= {land, labor, capital, food, manufacturing, services, capital goods}
TRAD_COMM	= {food, manufacturing, services}
DEMD_COMM	= {land, labor, capital, food, manufacturing, services}
PROD_COMM	= {food, manufacturing, services, capital goods}
ENDW_COMM	= {land, labor, capital}
ENDWS_COMM	= {land}
ENDWM_COMM	= {labor, capital}
CGDS_COMM	= {capital goods}
ENDWC_COMM	= {capital}

B Base Data

1 Value Flows

A VALUE FLOWS EVALUATED AT AGENTS' PRICES

$EVOA(i,r)$	value of endowment commodity i output or supplied in region r evaluated at agents' prices $EVOA(i,r) = PS(i,r) * QO(i,r)$	$\forall i \in ENDW\_COMM$ $\forall r \in REG$
$EVFA(i,j,r)$	value of purchases of endowment commodity i by firms in sector j of region r evaluated at agents' prices $EVFA(i,j,r) = PFE(i,j,r) * QFE(i,j,r)$	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
$VDFA(i,j,r)$	value of purchases of domestic tradeable commodity i by firms in sector j of region r evaluated at agents' prices $VDFA(i,j,r) = PFD(i,r) * QFD(i,r)$	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
$VIFA(i,j,r)$	value of purchases of imported tradeable commodity i by firms in sector j of region r evaluated at agents' prices $VIFA(i,j,r) = PFM(i,r) * QFM(i,r)$	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
$VDPA(i,r)$	value of expenditure on domestic tradeable commodity i by private household in region r evaluated at agents' prices $VDPA(i,r) = PPD(i,r) * QPD(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$VIPA(i,r)$	value of expenditure on imported tradeable commodity i by private household in region r evaluated at agents' prices $VIPA(i,r) = PPM(i,r) * QPM(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$VDGA(i,r)$	value of expenditure on domestic tradeable commodity i by government household in region r evaluated at agents' prices $VDGA(i,r) = PGD(i,r) * QGD(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$

VIGA(i,r)	value of expenditure on imported tradeable commodity *i* by government household in region *r* evaluated at agents' prices $VIGA(i,r) = PGM(i,r) * QGM(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
SAVE(r)	value of net savings in region *r* $SAVE(r) = PSAVE * QSAVE(r)$	$\forall r \in REG$
VDEP(r)	value of capital depreciation expenditure in region *r* $VDEP(r) = PCGDS(r) * DEPR(r) * KB(r)$	$\forall r \in REG$
VKB(r)	value of beginning-of-period capital stock in region *r* $VKB(r) = PCGDS(r) * KB(r)$	$\forall r \in REG$

B VALUE FLOWS EVALUATED AT MARKET PRICES

VFM(i,j,r)	value of purchases of endowment commodity *i* by firms in sector *j* of region *r* evaluated at market prices	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
	$VFM(i,j,r) = PM(i,r) * QFE(i,j,r)$ $= PMES(i,j,r) * QFE(i,j,r)$	$\forall i \in ENDWM\_COMM$ $\forall i \in ENDWS\_COMM$
VDFM(i,j,r)	value of purchases of domestic tradeable commodity *i* by firms in sector *j* of region *r* evaluated at market prices $VDFM(i,j,r) = PM(i,r) * QFD(i,r)$	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
VIFM(i,j,r)	value of purchases of imported tradeable commodity *i* by firms in sector *j* of region *r* evaluated at market prices $VIFM(i,j,r) = PIM(i,r) * QFM(i,r)$	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
VDPM(i,r)	value of expenditure on domestic tradeable commodity *i* by private household in region *r* evaluated at market prices $VDPM(i,r) = PM(i,r) * QPD(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$

VIPM(i,r)	value of expenditure on imported tradeable commodity *i* by private household in region *r* evaluated at market prices $VIPM(i,r) = PIM(i,r) * QPM(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
VDGM(i,r)	value of expenditure on domestic tradeable commodity *i* by government household in region *r* evaluated at market prices $VDGM(i,r) = PM(i,r) * QGD(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
VIGM(i,r)	value of expenditure on imported tradeable commodity *i* by government household in region *r* evaluated at market prices $VIGM(i,r) = PIM(i,r) * QGM(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
VXMD(i,r,s)	value of exports of tradeable commodity *i* from source *r* to destination *s* evaluated at (exporter's) market prices $VXMD(i,r,s) = PM(i,r) * QXS(i,r,s)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
VIMS(i,r,s)	value of imports of tradeable commodity *i* from source *r* to destination *s* evaluated at (importer's) market prices $VIMS(i,r,s) = PMS(i,r,s) * QXS(i,r,s)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
VST(i,r)	value of sales of tradeable commodity *i* to the international transport sector in region *r* evaluated at market prices $VST(i,r) = PM(i,r) * QST(i,r)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ *market prices*

C VALUE FLOWS EVALUATED AT WORLD PRICES

VXWD(i,r,s)	value of exports of tradeable commodity *i* from source *r* to destination *s* evaluated at world (*fob*) prices $VXWD(i,r,s) = PFOB(i,r,s) * QXS(i,r,s)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
VIWS(i,r,s)	value of imports of tradeable commodity *i* from source *r* to destination *s* evaluated at world (*cif*) prices $VIWS(i,r,s) = PCIF(i,r,s) * QXS(i,r,s)$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

2 *Technology, Preference, and Mobility Parameters*

SUBPAR(i,r)	substitution parameter for tradeable commodity *i* in the CDE minimum expenditure function of region *r*	$\forall i \in$ *TRAD_COMM* $\forall r \in$ *REG*
INCPAR(i,r)	income parameter for tradeable commodity *i* in the CDE minimum expenditure function of region *r*	$\forall i \in$ *TRAD_COMM* $\forall r \in$ *REG*
ESUBVA(j)	substitution parameter between primary factors in the CES value-added nest of the nested production structure of sector *j* of all regions	$\forall j \in$ *PROD_COMM*
ESUBD(i)	substitution parameter between domestic and composite imported commodities in the Armington utility/production structure of agent/sector *i* in all regions	$\forall i \in$ *TRAD_COMM*
ESUBM(i)	substitution parameter among imported commodities from different sources in the Armington utility/production structure of agent/sector *i* in all regions	$\forall i \in$ *TRAD_COMM*
ETRAE(i)	transformation parameter between uses for sluggish primary factor *i* in the one-level CET production structure in all regions	$\forall i \in$ *ENDWS_COMM*
RORFLEX(r)	flexibility of expected net rate of return on capital stock in region *r* with respect to investment (if a region's capital stock increases by 1%, then it is expected that the net rate of return on capital will decline by *RORFLEX*%)	$\forall r \in$ *REG*
RORDELTA	binary coefficient that determines the mechanism of allocating investment across regions [when *RORDELTA* = 1, investment is allocated across regions to equate the change in the expected rates of return, *rore(r)*, when *RORDELTA* = 0, investment is allocated across regions to maintain the existing composition of capital stocks]	

C Derivatives of the Base Data

1 Value Flows

$VOA(i,r)$ value of nonsavings commodity i output or supplied in region r evaluated at agents' prices — $\forall i \in NSAV\_COMM$, $\forall r \in REG$

$$VOA(i,r) = EVOA(i,r) \qquad \forall i \in ENDW\_COMM$$

$$VOA(i,r) = \sum_{j \in DEMD\_COMM} VFA(j,i,r) \qquad \forall i \in PROD\_COMM$$

$VFA(i,j,r)$ value of purchases of demanded commodity i by firms in sector j of region r evaluated at agents' prices — $\forall i \in DEMD\_COMM$, $\forall j \in TRAD\_COMM$, $\forall r \in REG$

$$VFA(i,j,r) = EVFA(i,j,r) \qquad \forall i \in ENDW\_COMM$$

$$VFA(i,j,r) = VDFA(i,j,r) + VIFA(i,j,r) \qquad \forall i \in TRAD\_COMM$$

$VOM(i,r)$ value of nonsavings commodity i output or supplied in region r evaluated at market prices — $\forall i \in NSAV\_COMM$, $\forall r \in REG$

$$VOM(i,r) = \sum_{j \in PROD\_COMM} VFM(i,j,r) \qquad \forall i \in ENDW\_COMM$$

$$VOM(i,r) = VDM(i,r) + \sum_{s \in REG} VXMD(i,r,s) + VST(i,r) \qquad \forall i \in TRAD\_COMM$$

$$VOM(i,r) = VOA(i,r) \qquad \forall i \in CGDS\_COMM$$

$VDM(i,r)$ value of domestic sales of tradeable commodity i in region r evaluated at market prices — $\forall i \in TRAD\_COMM$, $\forall r \in REG$

$$VDM(i,r) = VDPM(i,r) + VDGM(i,r) + \sum_{j \in PROD\_COMM} VDFM(i,j,r)$$

$VIM(i,r)$	value of aggregate imports of tradeable commodity i in region r evaluated at market prices $$VIM(i,r) = VIPM(i,r) + VIGM(i,r) + \sum_{j \in PROD\_COMM} VIFM(i,j,r)$$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$VPA(i,r)$	value of private household expenditure on tradeable commodity i in region r evaluated at agents' prices $$VPA(i,r) = VDPA(i,r) + VIPA(i,r)$$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$PRIVEXP(r)$	private household expenditure in region r evaluated at agents' prices $$PRIVEXP(r) = \sum_{i \in TRAD\_COMM} VPA(i,r)$$	$\forall r \in REG$
$VGA(i,r)$	value of government household expenditure on tradeable commodity i in region r evaluated at agents' prices $$VGA(i,r) = VDGA(i,r) + VIGA(i,r)$$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$GOVEXP(r)$	government household expenditure in region r evaluated at agents' prices $$GOVEXP(r) = \sum_{i \in TRAD\_COMM} VGA(i,r)$$	$\forall r \in REG$
$INCOME(r)$	expenditure in region r that equals net income (net of capital depreciation) $$INCOME(r) = PRIVEXP(r) + GOVEXP(r) + SAVE(r)$$	$\forall r \in REG$
$INC(r)$	initial value of income (expenditure) in the base data in region r stored as a parameter, used in calculating $EV(r)$ $$INC(r) = INCOME(r)$$	$\forall r \in REG$

REGINV(r) — gross investment in region r that equals value of output of sector "cgds" $\forall r \in REG$

$$REGINV(r) = \sum_{k \in CGDS\_COMM} VOA(k,r)$$

NETINV(r) — net investment in region r $\forall r \in REG$

$$NETINV(r) = \sum_{k \in CGDS\_COMM} VOA(k,r) - VDEP(r)$$

GLOBINV — global net investment

$$GLOBINV = \sum_{r \in REG} NETINV(r) = \sum_{r \in REG} SAVE(r)$$

INVKERATIO(r) — ratio of gross investment to end-of-period capital stock in region r $\forall r \in REG$

$$INVKERATIO(r) = \frac{REGINV(r)}{[VKB(r) + NETINV(r)]}$$

GRNETRATIO(r) — ratio of gross to net rate of return on capital in region r [*VOA("capital",r)* is gross return to capital] $\forall r \in REG$

$$GRNETRATIO(r) = \frac{\sum_{k \in ENDWC\_COMM} VOA(k,r)}{\left[\sum_{k \in ENDWC\_COMM} VOA(k,r) - VDEP(r)\right]}$$

GDP(r) — Gross domestic product in region r (trade is valued at world prices) $\forall r \in REG$

$$GDP(r) = \sum_{i \in TRAD\_COMM} VPA(i,r) + \sum_{i \in TRAD\_COMM} VGA(i,r) + \sum_{i \in CGDS\_COMM} VOA(i,r) + \sum_{i \in TRAD\_COMM} \sum_{s \in REG} [VXWD(i,r,s) + VST(i,r)] - \sum_{i \in TRAD\_COMM} \sum_{s \in REG} VIWS(i,s,r)$$

$VTWR(i,r,s)$	value of transportation services associated with the shipment of tradeable commodity i from source r to destination s (*fob* – *cif* margin) $$VTWR(i,r,s) = VIWS(i,r,s) - VXWD(i,r,s)$$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
VT	value of total international transportation services (sum of *fob* – *cif* margins across all commodities and all routes) $$VT = \sum_{i \in TRAD\_COMM} \sum_{r \in REG} \sum_{s \in REG} VTWR(i,r,s)$$	
$VXW(i,r)$	value of exports of tradeable commodity i from region r evaluated at world (*fob*) prices $$VXW(i,r) = \sum_{s \in REG} VXWD(i,r,s) + VST(i,r)$$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$VXWREGION(r)$	value of exports from region r evaluated at world (*fob*) prices $$VXWREGION(r) = \sum_{i \in TRAD\_COMM} VXW(i,r)$$	$\forall r \in REG$
$VWLDSALES(r)$	value of sales to the world market from region r evaluated at *fob* prices $$VWLDSALES(r) = \sum_{i \in TRAD\_COMM} \sum_{s \in REG} [VXWD(i,r,s) + VST(i,r)] + NETINV(r)$$	$\forall r \in REG$
$VXWCOMMOD(i)$	value of exports of tradeable commodity i evaluated at world (*fob*) prices $$VXWCOMMOD(i) = \sum_{r \in REG} VXW(i,r)$$	$\forall i \in TRAD\_COMM$
$VIW(i,r)$	value of imports of tradeable commodity i into region r evaluated at world (*cif*) prices $$VIW(i,r) = \sum_{s \in REG} VIWS(i,s,r)$$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$

VIWREGION(r) — value of imports into region *r* evaluated at world(*cif*) prices — $\forall r \in REG$

$$VIWREGION(r) = \sum_{i \in TRAD\_COMM} VIW(i,r)$$

VIWCOMMOD(i) — value of imports of tradeable commodity *i* evaluated at world (*cif*) prices — $\forall i \in TRAD\_COMM$

$$VIWCOMMOD(i) = \sum_{r \in REG} VIW(i,r)$$

VXWLD — value of worldwide commodity exports evaluated at *fob* prices

$$VXWLD = \sum_{r \in REG} VXWREGION(r) = \sum_{r \in REG} VIWREGION(r)$$

PW_PM(i,r) — ratio of world (*fob*) to domestic market prices for tradeable commodity *i* in region *r* — $\forall i \in TRAD\_COMM$, $\forall r \in REG$

$$PW\_PM(i,r) = \frac{\sum_{s \in REG} VXWD(i,r,s)}{\sum_{s \in REG} VXMD(i,r,s)}$$

VOW(i,r) — value of output of tradeable commodity *i* in region *r*, evaluated at world (*fob*) prices — $\forall i \in TRAD\_COMM$, $\forall r \in REG$

$$VOW(i,r) = VDM(i,r) * PW\_PM(i,r) + \sum_{s \in REG} VXWD(i,r,s) + VST(i,r)$$

VWOW(i) — value of world supply of tradeable commodity *i* evaluated at world (*fob*) prices — $\forall r \in REG$

$$VWOW(i) = \sum_{r \in REG} VOW(i,r)$$

2 *Shares*

SHRDFM(i,j,r) — share of domestic sales of tradeable commodity i used by firms in sector j of region r evaluated at market prices — $\forall i \in TRAD\_COMM$, $\forall j \in PROD\_COMM$, $\forall r \in REG$

$$SHRDFM(i,j,r) = \frac{VDFM(i,j,r)}{VDM(i,r)}$$

SHRDPM(i,r) — share of domestic sales of tradeable commodity i used by private household in region r evaluated at market prices — $\forall i \in TRAD\_COMM$, $\forall r \in REG$

$$SHRDPM(i,r) = \frac{VDPM(i,r)}{VDM(i,r)}$$

SHRDGM(i,r) — share of domestic sales of tradeable commodity i used by government household in region r evaluated at market prices — $\forall i \in TRAD\_COMM$, $\forall r \in REG$

$$SHRDGM(i,r) = \frac{VDGM(i,r)}{VDM(i,r)}$$

SHRIFM(i,j,r) — share of aggregate imports of tradeable commodity i used by firms in sector j of region r evaluated at market prices — $\forall i \in TRAD\_COMM$, $\forall j \in PROD\_COMM$, $\forall r \in REG$

$$SHRIFM(i,j,r) = \frac{VIFM(i,j,r)}{VIM(i,r)}$$

SHRIPM(i,r) — share of aggregate imports of tradeable commodity i used by private household in region r evaluated at market prices — $\forall i \in TRAD\_COMM$, $\forall r \in REG$

$$SHRIPM(i,r) = \frac{VIPM(i,r)}{VIM(i,r)}$$

$SHRIGM(i,r)$	share of aggregate imports of tradeable commodity i used by government household in region r evaluated at market prices $SHRIGM(i,r) = \frac{VIGM(i,r)}{VIM,(i,r)}$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$FMSHR(i,j,r)$	share of imports in the composite for tradeable commodity used by firms in sector j of region r evaluated at agents' prices $FMSHR(i,j,r) = \frac{VIFA(i,j,r)}{VFA(i,j,r)}$	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
$PMSHR(i,r)$	share of imports in the composite for tradeable commodity i used by private household in region r evaluated at agents' prices $PMSHR(i,r) = \frac{VIPA(i,r)}{VPA(i,r)}$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$GMSHR(i,r)$	share of imports in the composite for tradeable commodity i used by government household in region r evaluated at agents' prices $GMSHR(i,r) = \frac{VIGA(i,r)}{VGA(i,r)}$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
$CONSHR(i,r)$	budget share of the composite for tradeable commodity i in private household expenditure in region r evaluated at agents' prices $CONSHR(i,r) = \frac{VPA(i,r)}{PRIVEXP(r)}$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$

$MSHRS(i,r,s)$	market share of source r in the aggregate imports of tradeable commodity i in region s evaluated at market prices	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

$$MSHRS(i,r,s) = \frac{VIMS(i,r,s)}{\sum_{r \in REG} VIMS(i,r,s)}$$

$SVA(i,j,r)$	share of endowment commodity i in value-added of firms in sector j of region r evaluated at agents' prices	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

$$SVA(i,j,r) = \frac{VFA(i,j,r)}{\sum_{k \in ENDW\_COMM} VFA(k,j,r)}$$

$REVSHR(i,j,r)$	share of endowment commodity i used by firms in sector j of region r evaluated at market prices	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

$$REVSHR(i,j,r) = \frac{VFM(i,j,r)}{\sum_{k \in PROD\_COMM} VFM(i,k,r)}$$

$FOBSHR(i,r,s)$	share of *fob* price in the *cif* price for tradeable commodity i exported from source r to destination s	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

$$FOBSHR(i,r,s) = \frac{VXWD(i,r,s)}{VIWS(i,r,s)}$$

$TRNSHR(i,r,s)$	share of transport price in the *cif* price for tradeable commodity i exported from source r to destination s	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

$$TRNSHR(i,r,s) = \frac{VTWR(i,r,s)}{VIWS(i,r,s)}$$

D Variables

1 Quantity Variables

QO(i,r)	quantity of nonsaving commodity i output or supplied in region r	$\forall i \in NSAV\_COMM$ $\forall r \in REG$
QOES(i,j,r)	quantity of sluggish endowment commodity i supplied to firms in sector j of region r	$\forall i \in ENDWS\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
QDS(i,r)	quantity of domestic sales of tradeable commodity i in region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QXS(i,r,s)	quantity of exports of tradeable commodity i from source r to destination s	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
QST(i,r)	quantity of sales of tradeable commodity i to the international transport sector in region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QFE(i,j,r)	quantity of endowment commodity i demanded by firms in sector j of region r	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
QVA(j,r)	quantity index of value-added (land labor composite) in firms of sector j in region r	$\forall j \in PROD\_COMM$ $\forall r \in REG$
QF(i,j,r)	quantity of composite tradeable commodity i demanded by firms in sector j of region r	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
QFD(i,j,r)	quantity of domestic tradeable commodity i demanded by firms in sector j of region r	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

MSHRS(i,r,s)	market share of source *r* in the aggregate imports of tradeable commodity *i* in region *s* evaluated at market prices	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

$$MSHRS(i,r,s) = \frac{VIMS(i,r,s)}{\sum_{r \in REG} VIMS(i,r,s)}$$

SVA(i,j,r)	share of endowment commodity *i* in value-added of firms in sector *j* of region *r* evaluated at agents' prices	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

$$SVA(i,j,r) = \frac{VFA(i,j,r)}{\sum_{k \in ENDW\_COMM} VFA(k,j,r)}$$

REVSHR(i,j,r)	share of endowment commodity *i* used by firms in sector *j* of region *r* evaluated at market prices	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

$$REVSHR(i,j,r) = \frac{VFM(i,j,r)}{\sum_{k \in PROD\_COMM} VFM(i,k,r)}$$

FOBSHR(i,r,s)	share of *fob* price in the *cif* price for tradeable commodity *i* exported from source *r* to destination *s*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

$$FOBSHR(i,r,s) = \frac{VXWD(i,r,s)}{VIWS(i,r,s)}$$

TRNSHR(i,r,s)	share of transport price in the *cif* price for tradeable commodity *i* exported from source *r* to destination *s*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

$$TRNSHR(i,r,s) = \frac{VTWR(i,r,s)}{VIWS(i,r,s)}$$

D Variables

1 Quantity Variables

QO(i,r)	quantity of nonsaving commodity i output or supplied in region r	$\forall i \in NSAV\_COMM$ $\forall r \in REG$
QOES(i,j,r)	quantity of sluggish endowment commodity i supplied to firms in sector j of region r	$\forall i \in ENDWS\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
QDS(i,r)	quantity of domestic sales of tradeable commodity i in region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QXS(i,r,s)	quantity of exports of tradeable commodity i from source r to destination s	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
QST(i,r)	quantity of sales of tradeable commodity i to the international transport sector in region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QFE(i,j,r)	quantity of endowment commodity i demanded by firms in sector j of region r	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
QVA(j,r)	quantity index of value-added (land labor composite) in firms of sector j in region r	$\forall j \in PROD\_COMM$ $\forall r \in REG$
QF(i,j,r)	quantity of composite tradeable commodity i demanded by firms in sector j of region r	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
QFD(i,j,r)	quantity of domestic tradeable commodity i demanded by firms in sector j of region r	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

QFM(i,j,r)	quantity of imported tradeable commodity *i* demanded by firms in sector *j* of region *r*	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
QP(i,r)	quantity of composite tradeable commodity *i* demanded by private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QPD(i,r)	quantity of domestic tradeable commodity *i* demanded by private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QPM(i,r)	quantity of imported tradeable commodity *i* demanded by private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QG(i,r)	quantity of composite tradeable commodity *i* demanded by government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QGD(i,r)	quantity of domestic tradeable commodity *i* demanded by government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QGM(i,r)	quantity of imported tradeable commodity *i* demanded by government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QIM(i,r)	quantity of aggregate imports of tradeable commodity *i* demanded by region *r* using market prices as weights	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QIW(i,r)	quantity of aggregate imports of tradeable commodity *i* demanded by region *r* using *cif* prices as weights	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QXW(i,r)	quantity of aggregate exports of tradeable commodity *i* supplied from region *r* using *fob* prices as weights	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
QIWREG(r)	volume of merchandise imports demanded by region *r*	$\forall r \in REG$
QXWREG(r)	volume of merchandise exports supplied by region *r*	$\forall r \in REG$
QIWCOM(i)	volume of global merchandise imports of tradeable commodity *i*	$\forall i \in TRAD\_COMM$
QXWCOM(i)	volume of global merchandise exports of tradeable commodity *i*	$\forall i \in TRAD\_COMM$

QXWWLD	volume of world trade	
QOW(i)	quantity index for world supply of tradeable commodity *i*	$\forall i \in$ *TRAD_COMM*
QT	quantity of global transport services supplied	
QCGDS(r)	quantity of capital goods sector supplied in region *r*	$\forall r \in$ *REG*
QSAVE(r)	quantity of savings demanded in region *r*	$\forall r \in$ *REG*
GLOBALCGDS	quantity of global supply of capital for net investment	
KSVCES(r)	quantity of capital services in region *r*	$\forall r \in$ *REG*
KB(r)	quantity of beginning-of-period capital stock in region *r*	$\forall r \in$ *REG*
KE(r)	quantity of end-of-period capital stock in region *r*	$\forall r \in$ *REG*
POP(r)	population in region *r*	$\forall r \in$ *REG*
QGDP(r)	quantity index for GDP in region *r*	$\forall r \in$ *REG*
WALRAS_DEM	quantity demanded in the omitted market (equals global demand for savings)	
WALRAS_SUP	quantity supplied in the omitted market (equals global supply of new capital goods composite)	

2 *Price Variables*

PS(i,r)	supply price of nonsavings commodity *i* in region *r*	$\forall i \in$ *NSAV_COMM* $\forall r \in$ *REG*
PM(i,r)	market price of nonsavings commodity *i* in region *r*	$\forall i \in$ *NSAV_COMM* $\forall r \in$ *REG*
PMES(i,j,r)	market price of sluggish endowment commodity *i* supplied to firms in sector *j* of region *r*	$\forall i \in$ *ENDWS_COMM* $\forall j \in$ *PROD_COMM* $\forall r \in$ REG
PFE(i,j,r)	demand price of endowment commodity *i* for firms in sector *j* of region *r*	$\forall i \in$ *ENDW_COMM* $\forall j \in$ *PROD_COMM* $\forall r \in$ *REG*

PVA(j,r)	price of value-added in sector *j* of region *r*	$\forall j \in PROD\_COMM$ $\forall r \in REG$
PF(i,j,r)	demand price of composite tradeable commodity *i* for firms in sector *j* of region *r*	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
PFD(i,j,r)	demand price of domestic tradeable commodity *i* for firms in sector *j* of region *r*	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
PFM(i,j,r)	demand price of imported tradeable commodity *i* for firms in sector *j* of region *r*	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
PP(i,r)	demand price of composite tradeable commodity *i* for private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PPD(i,r)	demand price of domestic tradeable commodity *i* for private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PPM(i,r)	demand price of imported tradeable commodity *i* for private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PG(i,r)	demand price of composite tradeable commodity *i* for government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PGD(i,r)	demand price of domestic tradeable commodity *i* for government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PGM(i,r)	demand price of imported tradeable commodity *i* for government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PPRIV(r)	price index for private household expenditure in region *r*	$\forall r \in REG$
PGOV(r)	price index for government household expenditure in region *r*	$\forall r \in REG$

PFOB(i,r,s)	world (*fob*) price of tradeable commodity i exported from source r to destination s (prior to including transport margin)	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
PCIF(i,r,s)	world (*cif*) price of tradeable commodity i imported from source r to destination s (after including transport margin)	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
PMS(i,r,s)	market price by source of tradeable commodity i imported from source r to destination s	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
PIM(i,r)	market price of aggregate imports of tradeable commodity i in region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PIW(i,r)	world price of aggregate imports of tradeable commodity i in region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PXW(i,r)	price index for aggregate exports of tradeable commodity i from region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PIWREG(r)	price index of merchandise imports in region r	$\forall r \in REG$
PXWREG(r)	price index of merchandise exports from region r	$\forall r \in REG$
PIWCOM(i)	price index of global merchandise imports of tradeable commodity i	$\forall i \in TRAD\_COMM$
PXWCOM(i)	price index of global merchandise exports of tradeable commodity i	$\forall i \in TRAD\_COMM$
PXWWLD	price index of world trade	
PR(i,r)	ratio of domestic market price to market price of imports for tradeable commodity i in region r	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
PW(i)	world price index for total supply of tradeable commodity i	$\forall i \in TRAD\_COMM$
PSW(r)	price index received for tradeables produced in region r including sales of net investment to the global bank	$\forall r \in REG$

PDW(r)	price index paid for tradeables used in region *r* including purchases of savings from the global bank	$\forall r \in REG$
TOT(r)	terms of trade for region *r* $TOT(r) = [PSW(r) / PDW(r)]$	$\forall r \in REG$
PT	price of global transport services supplied	
PCGDS(r)	price of investment goods in region *r* [equals *PS*("*cgds*", *r*)]	$\forall r \in REG$
PSAVE	price of composite capital good supplied to savers by global bank	
RENTAL(r)	rental rate on capital stock in region *r* [equals *PS*("*capital*", *r*)]	$\forall r \in REG$
RORC(r)	current net rate of return on capital stock in region *r*	$\forall r \in REG$
RORE(r)	expected net rate of return on capital stock in region *r*	$\forall r \in REG$
RORG	global net rate of return on capital stock	
PGDP(r)	price index for GDP in region *r*	$\forall r \in REG$

3 *Policy Variables*

TO(i,r)	power of the tax on output (or income) of nonsavings commodity *i* in region *r*	$\forall i \in NSAV\_COMM$ $\forall r \in REG$
TF(i,j,r)	power of the tax on endowment commodity *i* demanded by firms in sector *j* of region *r*	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
TFD(i,j,r)	power of the tax on domestic tradeable commodity *i* demanded by firms in sector *j* of region *r*	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
TFM(i,j,r)	power of the tax on imported tradeable commodity *i* demanded by firms in sector *j* of region *r*	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

TPD(i,r)	power of the tax on domestic tradeable commodity *i* demanded by private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
TPM(i,r)	power of the tax on imported tradeable commodity *i* demanded by private household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
TGD(i,r)	power of the tax on domestic tradeable commodity *i* demanded by government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
TGM(i,r)	power of the tax on imported tradeable commodity *i* demanded by government household in region *r*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
TXS(i,r,s)	power of the tax on exports of tradeable commodity *i* from source *r* to destination *s* (levied in region *r*)	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
TMS(i,r,s)	power of the tax on imports of tradeable commodity *i* from source *r* to destination *s* (levied in region *s*)	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
TX(i,r)	power of the variable export tax on exports of tradeable commodity *i* from region *r*–destination-generic	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
TM(i,r)	power of the variable import tax (levy) on imports of tradeable commodity *i* in region *s*–source-generic	$\forall i \in TRAD\_COMM$ $\forall r \in REG$

4 *Technical Change Variables*

AO(j,r)	output augmenting technical change in sector *j* of region *r*	$\forall j \in PROD\_COMM$ $\forall r \in REG$
AFE(i,j,r)	primary factor *i* augmenting technical change in sector *j* of region *r*	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$

AF(i,j,r)	composite intermediate input *i* augmenting technical change in sector *j* of region *r*	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
AVA(j,r)	value-added augmenting technical change in sector *j* of region *r*	$\forall j \in PROD\_COMM$ $\forall r \in REG$
ATR(i,r,s)	technical change in the transportation of tradeable commodity *i* from source *r* to destination *s*	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$

5 *Dummy (0, 1) Variables*

D_EVFA(i,j,r)	0, 1 variable for identifying zero expenditures in *EVFA(i,j,r)* $D\_EVFA(i,j,r) = 0$ $D\_EVFA(i,j,r) = 1 \ \forall \ EVFA(i,j,r) > 0$	$\forall i \in ENDW\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
D_VFA(i,j,r)	0, 1 variable for identifying zero expenditures in *VFA(i,j,r)* $D\_VFA(i,j,r) = 0$ $D\_VFA(i,j,r) = 1 \ \forall \ VFA(i,j,r) > 0$	$\forall i \in TRAD\_COMM$ $\forall j \in PROD\_COMM$ $\forall r \in REG$
D_VXWD(i,r,s)	0, 1 variable for identifying zero expenditures in *VXWD(i,r,s)* $D\_VXWD(i,r,s) = 0$ $D\_VXWD(i,r,s) = 1 \ \forall \ VXWD(i,r,s) > 0$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$ $\forall s \in REG$
D_VST(i,r)	0, 1 variable to identify zero expenditures in *VST(i,r)* $D\_VST(i,r) = 0$ $D\_VST(i,r) = 1 \ \forall \ VST(i,r) > 0$	$\forall i \in TRAD\_COMM$ $\forall r \in REG$

6 *Slack Variables*

profitslack(j,r)	slack variable in the ZEROPROFITS equation [this is exogenous as long as output, *QO(j,r)*, is endogenous]	$\forall j \in PROD\_COMM$ $\forall r \in REG$
cgdslack(r)	slack variable in the RORGLOBAL equation [this is exogenous as long as output of capital goods, *QO("cgds",r)*, is endogenous]	$\forall r \in REG$
endwslack(i,r)	slack variable in the MKTCLENDWM and ENDW_SUPPLY equations [this is exogenous as long as primary factor rental rates, *PM(i,r)* and *PMES(i,j,r)*, are endogenous]	$\forall i \in ENDW\_COMM$ $\forall r \in REG$
tradslack(i,r)	slack variable in the MKTCLTRD equation [this is exogenous as long as price of tradeable, *PM(i,r)*, is endogenous]	$\forall i \in TRAD\_COMM$ $\forall r \in REG$
incomeslack(r)	slack variable in the REGIONALINCOME equation [this is exogenous as long as regional household income, *Y*(r), is endogenous]	$\forall r \in REG$
saveslack(r)	slack variable in the SAVINGS equation [this is exogenous as long as savings, *QSAVE(r)*, is endogenous]	$\forall r \in REG$
govslack(r)	slack variable in the GOVERTU equation [this is exogenous as long as real government purchases, *UG(r)*, is endogenous]	$\forall r \in REG$
walraslack	slack variable in the WALRAS equation [this is exogenous as long as price of savings, *PSAVE*, is endogenous as is the case in a *standard GE closure*. When any one of the GE links is broken, this is swapped with *PSAVE*, the numeraire price, thereby forcing global savings to equal global investment]	

7 *Value and Income Variables*

vxwfob(i,r)	percentage change in value of exports of tradeable commodity *i* from region *r* using *fob* weights [is identical to the linearized form of *VXW(i,r)*]	$\forall i \in$ *TRAD_COMM* $\forall r \in$ *REG*
vxwreg(r)	percentage change in value of merchandise exports from region *r* using *fob* weights [is identical to the linearized form of *VXWREGION(r)*]	$\forall r \in$ *REG*
vxwcom(i)	percentage change in value of global merchandise exports of tradeable commodity *i* using *fob* weights [is identical to the linearized form of *VXWCOMMOD(i)*]	$\forall i \in$ *TRAD_COMM*
viwcif(i,r)	percentage change in value of imports of tradeable commodity *i* into region *r* using *cif* weights [is identical to the linearized form of *VIW(i,r)*]	$\forall i \in$ *TRAD_COMM* $\forall r \in$ *REG*
viwreg(r)	percentage change in value of merchandise imports into region *r* using *cif* weights [is identical to the linearized form of *VIWREGION(r)*]	$\forall r \in$ *REG*
viwcom(i)	percentage change in value of global merchandise imports of tradeable commodity *i* using *cif* weights [is identical to the linearized form of *VIWCOMMOD(i)*]	$\forall i \in$ *TRAD_COMM*
vxwwld	percentage change in value of worldwide commodity exports using *fob* weights [is identical to the linearized form of VXWLD])	
valuew(i)	percentage change in value of global supply of tradeable commodity *i* using *fob* weights [is identical to the linearized form of *VWOW(i)*]	$\forall i \in$ *TRAD_COMM*
vgdp(r)	percentage change in value of GDP in region *r* [is identical to the linearized form of *GDP(r)*]	$\forall r \in$ *REG*
y(r)	percentage change in regional household income in region *r* [is identical to the linearized form of *INCOME(r)*]	$\forall r \in$ *REG*
yp(r)	percentage change in private household expenditure in region *r* [is identical to the linearized form of *PRIVEXP(r)*]	$\forall r \in$ *REG*

8 *Utility Variables*

U(*r*)	per capita utility from aggregate household expenditure in region *r*	$\forall r \in REG$
UP(*r*)	per capita utility from private household expenditure in region *r*	$\forall r \in REG$
UG(*r*)	aggregate utility from government household expenditure in region *r*	$\forall r \in REG$

9 *Welfare Variables*

EV(*r*)	equivalent variation in region *r*, in $US million (positive figure indicates welfare improvement)	$\forall r \in REG$
WEV	equivalent variation for the world, in $US million (positive figure indicates welfare improvement)	

10 *Trade Balance Variables*

DTBAL(*r*)	change in trade balance of region *r*, in $US million (positive figure indicates increase in exports exceeds increase in imports)	$\forall r \in REG$
DTBALi(*i*,*r*)	change in trade balance for tradeable commodity *i* in region *r*, in $US million (positive figure indicates increase in exports exceeds increase in imports)	$\forall i \in TRAD\_COMM$ $\forall r \in REG$

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Printed in the United States
124817LV00002B/181-183/A

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