3

The CGE Model Database: A Social Accounting Matrix

In this chapter, we describe the computable general equilibrium (CGE) model database. The database reports the value of all transactions in an economy during a period of time. The database can be organized and displayed as a Social Accounting Matrix (SAM), a logical framework that provides a visual display of the transactions as a circular flow of national income and spending. The SAM's microeconomic data describe transactions made by each agent in the economy. When aggregated, the SAM's microdata describe the economy's macroeconomic behavior. The SAM's microdata can also be used to calculate descriptive statistics on an economy's structure and tax rates.

Introduction to the Social Accounting Matrix

The database of a CGE model reports the value of all transactions in the circular flow of national income and spending in an economy over a specified period of time, usually a year. The model database that we use throughout this book, for demonstration, describes economic activity in the United States and the rest-of-world economies during 2004.

A CGE model's database can be organized into a table called a ***Social Accounting Matrix*** (SAM) (see Text Box 3.1). The SAM table is a logical arrangement of the model's database to provide an easy-to-read, visual display of the linkages among ***agents*** in the economy. Agents typically include industries, factors of production (e.g., labor and capital), household consumers, the government, and the rest-of-world region, which supplies imports and demands exports.

A SAM is a square matrix of data. It is square because every economic agent in the economy has both a column account and a row account. The SAM's column accounts record each agent's spending. Row accounts record each agent's sources of income. Therefore, every cell in the SAM matrix describes a single transaction as being simultaneously an expenditure by an agent's column account and the receipt of income by an agent's row account.

Text Box 3.1. Key Features of a SAM

- A SAM is a square matrix because each agent has both a column and a row account.
- Column accounts record spending.
- Row accounts record income.
- Each cell in the SAM is simultaneously an expenditure by an agent and a source of income to an agent.
- For each agent, total expenditure (column account total) must equal total income (row account total).

This procedure for recording transactions visually records how any single transaction links agents in the economy.

Table 3.1 shows a simple example of the SAM accounting framework. There are two agents: a farmer and a baker. Each agent has both a row account and a column account. The farmer's expenditure of \$1 on bread is reported in his column (expenditure) account, "Farmer spending," and his income of \$1 from the sale of wheat to the baker is reported in his row (income) account, "Farmer income." The baker's expenditure of \$1 on wheat is reported in the column account "Baker spending;" and her income of \$1 from the sale of bread to the farmer is reported in the row account, "Baker income." Note that the \$1 that the farmer spends on bread is simultaneously the \$1 earned by the baker on the sale of bread. This single cell therefore reports both sides of the same transaction. Finally, the incomes of the farmer and the baker of \$1 are equal to their expenditures of \$1.

The SAM format enables the modeler to verify visually that the initial database is balanced. A SAM is balanced when every agent meets this constraint: Total spending (its column sum) equals total income (its row sum). For example, by comparing the baker's column sum with her row sum you may easily verify that her income of \$1 is equal to her expenditure of \$1. When income is equal to spending in every account, then the economy's aggregate spending is equal to its aggregate income, and the database describes an economy in an initial equilibrium. A CGE model requires a balanced database

Table 3.1. *A Two-agent SAM*

	Farmer Spending	Baker Spending	Total Income
Farmer income		Baker buys \$1 wheat from farmer	Farmer income = \$1
Baker income	Farmer buys \$1 bread from baker		Baker income = \$1
Total spending	Farmer spending = \$1	Baker spending = \$1	

as an initial starting point. As we will see in later chapters, model shocks will disturb this equilibrium. Price, supply and demand will then readjust until the economy is in a new equilibrium in which income again is equal to expenditure for all agents in the economy.

Accounts in a SAM

The SAMs used in CGE models usually contain more accounts than in our simple example of the transactions between the farmer and the baker. SAMs contain accounts that describe the incomes and spending of all agents in the model. Additional accounts describe income transfers among agents such as tax payments by labor to the government. SAMs also include a financial account to describe the sources of national savings and investment spending.

Throughout this book, we will study a SAM for the United States in 2004 (Appendix Table). In this SAM, the circular flow begins with a description of the production process. (It does not matter in which order accounts are presented in a SAM, although it is the convention that the ordering of row accounts is the same as that of columns.) The SAM reports each industry's purchases of intermediate inputs and payments to the labor and capital that it employs. In turn, wage and capital rental payments provide income to households. The SAM reports all tax revenue paid to the government and the value of household plus government savings (or dissaving), which funds investment spending. Together, households, government, and investors purchase goods and services, which leads back to demand for industries' output and their spending on inputs and factors. The SAM also reports trade and foreign savings inflows or outflows.

The accounts included in SAMs often differ across CGE models. They may differ in dimensions; that is, in their number of industries, factors of production, or household types. For example, some SAMs may have accounts that divide an economy into two industries, such as mining and nonmining industries, while other SAMs may have accounts for 400 or more industries. The U.S. SAM that we study in this book has three industries – agriculture, manufacturing, and services; three factors – land, labor and capital; and one household type. That is why we call it the U.S. 3x3 SAM.

SAMs' accounts can differ, too, because the structure and theory of the CGE models in which they are used differ. A SAM and its CGE model must be consistent with each other. For example, one CGE model may include a regional household while another model does not. Their SAMs will differ in that case – one will include row and column accounts for a regional household while the other will not. Note, too, that even when the accounts of two SAMs are identical, the location of data in their cells can differ. This point is particularly important for tax data. Taxes' cell locations describe the transactions in the CGE model on which each tax is assumed to be levied. For example, a retail sales tax should appear as a cost in the household consumer's spending column.

Studying the accounts and the cell locations of data in your SAM model is a good first step in learning about your CGE model. This study can help you to identify both visually and intuitively the industries and agents in your model, their economic interrelationships, and the activities on which taxes are levied.

Table 3.2 presents a summary of the accounts typically found in SAMs. This summary, and the U.S. SAM that we will study, are compatible with the Global Trade Analysis Project (GTAP) CGE model, which we use for demonstration throughout this book. You can use the U.S. 3x3 SAM to follow along as we discuss each of the accounts in a SAM in detail.

Production Activities

A production **activity** is a domestic industry engaged in the production of a good or service. An activity's column account describes all of its expenditures on the inputs used in its production process. For example, the column account for the U.S. agricultural activity records its purchases of imported and domestically produced intermediate inputs. These include agricultural inputs such as seeds, manufactured inputs such as fertilizer, and services such as bookkeeping. The remaining inputs – the sum of wages, rents, and tax expenditures – is called an industry's ***value-added***. The column sum for an activity is the value of its ***gross output***. Gross output is value-added plus the costs of all intermediate inputs. In the U.S. 3x3 SAM for 2004 (see Appendix Table), for example, the value of gross output by the agriculture production activity is $434 billion.

An activity's row account records where the industry sells its output. Production activities are usually assumed to sell their entire output to a commodity account. This transaction is explained more fully in the description of commodity accounts.

Sometimes, the same good is produced in more than one way. Agricultural production in Arizona, for example, may require types of irrigation equipment not needed by farmers in California. A modeler interested in studying the two types of agricultural industries can expand the SAM by dividing the agricultural production activity into two separate activity accounts, each with its own row and column. In our example, separate Arizona and California agriculture column accounts would report purchases of very different types of inputs, even though the two activities produce the same type of output. Their row accounts would report their sales of an identical product to the same commodity account – "agriculture."

Table 3.2. *Accounts in a Social Accounting Matrix with a Regional Household*

		Commodities				Final Demand						
	Production Activities	Import Variety	Domestic Variety	Factors	Taxes	Regional Household	Private Households	Government	Savings–Investment	Trade Margins	Rest-of-World	Total
Production activities			Domestic production									Domestic sales
Commodities Imports	Demand for imported intermediates						Demand for imports	Demand for imports	Demand for imports			Aggregate demand
Domestic	Demand for domestic intermediates						Demand for domestic	Demand for domestic	Demand for domestic	Export of trade margins	Exports	
Factors of production	Factor payments											Factor income
Taxes	Taxes on productionoutput, factor use, inputs	Import tariff	Export tax	Income tax			Sales tax	Sales tax	Sales tax			Tax revenue
Regional household				Net factor income	Tax revenues							Aggregate income
Private household						Household income						Private household income
Government						Government income						Government income
Savings–investment				Depreciation		Domestic savings				Foreign savings	Foreign savings	Savings
Trade margins		Trade margins on imports										Foreign exchange outflow
Rest-of-world		Imports										
Total	Gross value of production	Aggregate supply		Factor expenditure	Tax expenditure	Aggregate expenditure	Private consumption expenditure	Government consumption expenditure	Investment expenditure	Foreign exchange inflow		

Text Box 3.2. Disaggregated Production Regions and Households in a SAM for Morocco

"Policy Options and Their Potential Effects on Moroccan Small Farmers and the Poor Facing Increased World Food Prices: A General Equilibrium Model Analysis." (Diao, Doukkali, and Yu, 2008).

What is the research question? World food prices have increased sharply over recent years and do not appear likely to return to 2000–03 levels. How will higher food prices affect different production regions and household types in Morocco, which is dependent on food imports for a large share of its domestic consumption?

What is the CGE model innovation? The authors modify the IFPRI standard CGE model to account for disaggregated production regions and households in the SAM. They construct a SAM for Morocco that divides each agricultural production activity account into six agroecological regions, each with a different production technology. The household accounts in the SAM are disaggregated into ten representative groups consistent with the income deciles of rural and urban households.

What is the model experiment? World import and export prices of food are increased, based on price projections from the U.S. Department of Agriculture. Three mitigating policy options are modeled: (1) import tariff reforms, (2) import subsidies to the poor, and (3) compensatory direct transfer payments (negative income taxes) to poor households.

What are the key findings? Direct transfers to poor consumers combined with increased public investment in agriculture to improve productivity, is a win-win strategy for Morocco's agricultural producers and consumers.

Modelers sometimes use this technique of subdividing activity accounts in order to create CGE models that subdivide a national economy into regions. Text Box 3.2 describes a research project in which the CGE modelers subdivided the activity accounts of a SAM for Morocco to describe the production of the same agricultural good in different regions and using different production technologies.

Commodities

A **commodity** is an economy's total supply of a good or service from domestic production and imports, combined. For example, the U.S. supply of the commodity "automobiles" is the sum of domestically produced varieties, such as Ford Tauruses, plus imported varieties, like Japanese Toyotas.

In the SAM, commodity column accounts might be thought of as wholesale packagers who purchase goods and services from domestic producers and combine them with imported varieties to create the "bundle," or composite commodity, that consumers purchase. In the U.S. 3x3 SAM, for example, the agricultural commodity account describes the sourcing of agricultural goods from imports and domestic production. The agricultural commodity is composed of \$434 billion worth of domestically produced agricultural products and \$177 billion worth of agricultural imports (shown as the column totals of the imports and domestic commodity columns). The total supply of the agricultural commodity is \$611 billion.

The commodity row accounts show where goods are sold. Thus, while the activity accounts in the SAM describe the supply side of the model, the commodity row accounts describe the demand side of the model. Production activities, households, government, and investors all demand commodities, and some share of domestic production is used to satisfy export demand. In the U.S. SAM, for example, the domestic variety of the agricultural commodity is sold to production activities as an intermediate input (\$24 + \$229 + \$70 = \$323), to private households (\$60 billion), to the government (\$1 billion), and as exports (\$50 billion).

Each of the domestic customers may demand different proportions of the imported and domestic varieties in their commodity bundle. In the U.S. SAM, for example, \$2 billion of the imported variety and \$24 billion of the domestically produced variety of the agricultural commodity are purchased by the agricultural production activity. The import share in its use of agricultural inputs is $2/26 * 100 = 8$ percent. Private households purchase \$9 billion of the imported variety of agriculture and \$60 billion of the domestically produced variety. In this case, households import 13 percent of their total agricultural consumption.

In most CGE models, each good or service has both an activity account and a matching commodity account. That is, if there is an electricity production activity account, there is also an electricity commodity account to which it is sold. However, this one-to-one correspondence is not necessary. Some production activities can have multiple products, such as a livestock operation that produces beef and cowhides. In this case, the livestock activity account could sell its output to separate beef and leather commodity accounts. Or, if we disaggregated manufacturing production activities by all fifty U.S. states, a single commodity account called "manufacturing" could purchase the same output, "manufacturing," from fifty different manufacturing production activities.

Factors of Production

Factors of production are the resource endowments of land, labor, and capital that are combined with intermediate inputs such as steel, rubber gaskets and electronic components, to produce goods and services. The factors in the U.S. 3x3 SAM are labor, capital, and land. Some modelers further subdivide these factor types. For example, labor may be divided into skilled and unskilled workers, or land divided into cropland and forest, or irrigated and nonirrigated. You can visualize the disaggregation of factors in a SAM by imagining that there is a new factor column and a matching row account for each additional factor in the model.

The row account for each factor reports the income it receives from the production activities in which it is employed. Production activities pay wages to labor and rents to capital and land. In the U.S. 3x3 SAM, for example, the manufacturing production activity pays \$1,109 billion in wages to its labor force and \$467 billion in rents to capital equipment.

The factor column accounts report factor expenditure. In the U.S. 3x3 SAM, for example, the land column account reports that \$31 billion in land factor income flows to the regional household, and \$3 billion is spent on income taxes. The capital income account in addition records capital depreciation as an expenditure in the savings-investment row account.

Taxes

The tax row accounts in a SAM describe the economic activities on which taxes are levied and the amount of tax revenue that is generated. For example, in the U.S. 3x3 SAM, production activities pay production taxes (from their column accounts) to the production tax row account. The agricultural production activity spends \$4 billion on this tax. Tax column and row sums report the value of total revenue from each tax, which is paid by the column account for each tax to the regional household account. In the U.S. SAM, for example, production taxes generate a total of \$469 billion in revenue and income taxes generate \$1,693 billion in revenue.

Regional Household

A regional household is a macroeconomic account found in some SAMs and CGE models. It is similar to the concept of GDP from the income side and from the expenditure side. It is row describes the sources of aggregate national income from factor incomes and taxes, and its column describes allocation to aggregate domestic spending by private households and government, and to national savings.[1] In the U.S. 3x3 SAM, for example, the regional household accrues factor incomes (net of income tax) along its row account: \$31 + \$5,397 + \$1,632 = \$7,060 billion. It also earns tax income from trade taxes, sales taxes, factor use, production, and income taxes, for a total regional income of \$10,628 billion. The regional household column account shows how national income is allocated to spending by private households

[1] The regional household account differs from GDP because it excludes depreciation. For example, in the U.S. 3x3 SAM, regional household income is \$10,627.9 billion, GDP is \$11,673.4 billion, and depreciation is \$1045.5 billion.

($8,233 billion) and government ($1,810 billion) and to domestic savings ($585 billion, combining private and public savings).[2]

Private Households

The **private household** row and column accounts describe the income and spending of all of the individuals in an economy, aggregated into a single, representative "household." The private household row account receives after-income-tax income from the regional household's column account. Households spend this income in its entirety on goods and services and related sales taxes, as described in the household's column account. Private household consumption is usually a large component of an economy's final demand for goods and services. In the U.S. 3x3 SAM, for example, households spend $8,233 billion, which dwarfs spending by government and investors.

Sometimes, SAMs (and their related CGE models) disaggregate the single household into several representative household types. They may be disaggregated according to criteria such as sources of income (perhaps one type earns low-skilled wages, and the other type earns high-skilled wages), or location (e.g., rural or urban), or expenditure patterns (e.g., high or low share of spending on food). Disaggregating households allows the modeler to analyze the distributional effects of an economic shock across different household types. For example, a new tax may benefit rural households but impose a burden on urban households.

You can visualize a SAM with many households by imagining that the single private household row and column accounts in the U.S. 3x3 SAM are disaggregated into *n* household row accounts and *n* household column accounts, each describing the different income sources and expenditure patterns of *n* household types.

Government

The **government** row and column accounts report government income and its expenditure on goods and services. In the U.S. 3x3 SAM, the government account receives $1,810 billion from the regional household, and spends it almost exclusively on services.

Savings-investment

This row account reports the sources of a nation's savings. In the U.S. 3x3 SAM, the savings row account shows the accumulation of saving from

[2] Breisinger, Thomas, and Thurlow (2009), Reinert and Roland-Holst (1997) and Pyatt and Round (1985) offer nontechnical introductions to SAMs without a regional household account.

domestic sources ($585 billion). Foreign savings ($536 + $32 = $568 billion) equals the trade balance in goods and services and in trade margin services. Depreciation of the existing capital stock, which totals $1,046 billion, is also recorded. The investment column account records investors' purchases of the goods and services that will be used in future production activities, and related sales taxes. In the U.S. 3x3 SAM, investment spending totals $2,198 billion. The SAM does not indicate in which industries the investment goods are installed.

Trade Margins

These accounts describe the insurance, and freight charges which are incurred when goods are shipped by air, sea, or overland from an exporting country to the importing country. These costs raise the price of imports relative to the price received by the exporters. The exporter's margin exclusive-price is called the free on board, or *fob* price. The importer's margin-inclusive price is called the *cif* price. The difference between the *cif* and *fob* values of imports is the trade margin.

In the SAM, there are trade margin accounts for both imports and exports. For imports, the trade margin row account records the freight and insurance costs incurred for each imported good. For example, the United States spends $9 billion on margin services to import $167 billion worth of agricultural products. It spends a total of $56 billion on trade margin charges on its total imports. The exports trade margin column account reports the value of trade margin services produced by the United States and exported for use in global trade.[3] The United States exports $24 billion in margin services. Because trade margins are essentially the export and import of a type of service, a country has a balance of trade in trade margin services. It is the value of trade margin exports minus trade margin imports and reported as a foreign capital inflow or outflow in the savings-investment row. The United States has a trade deficit in margin services, resulting in a foreign savings inflow of $32 billion.

Rest-of-World

This account describes trade and investment flows between a country and the rest of the world (ROW). The row account in the SAM shows the home country's foreign exchange outflow, which is its spending on each import valued in ROW's *fob* world export prices. The ROW column account reports the home country's foreign exchange inflow, or export sales of each commodity, valued in the home country's *fob* world export prices. The column

[3] Export margin data are not tracked bilaterally in the GTAP database from which our SAM is derived.

account also records the balance of trade as a payment by, or inflow from, the rest-of-world to the savings-investment account. The balance of trade is the difference between the *fob* values of the home country's total exports and total imports. When the country runs a trade deficit (its imports exceed its exports), its foreign savings inflow is positive. In this case, the country is borrowing from abroad and the foreign savings inflow increases its supply of savings. When a country runs a trade surplus (the value of its exports exceed the value of its imports), its foreign savings inflow is negative. In effect, it is lending its capital to foreigners. In the U.S. 3x3 SAM, imports of goods and services worth $1,601 billion and exports of $1,056 trillion result in a foreign savings inflow to the United States (a trade deficit) of $536 billion.

Microeconomic Data in a SAM

A SAM database presents microeconomic data. Microeconomic data describe a nation's economic activity in detail. For example, the SAM's microeconomic data on production describe the amount spent by each industry on each type of intermediate and factor input, and each type of tax. Its data on domestic demand describe expenditure on each type of commodity by each agent in the economy. Microeconomic data on trade describe the commodity composition of imports and exports. Even when the modeler chooses to summarize an economy into a relatively small number of industries or factors, we still consider the SAM to be a presentation of microeconomic data.

Macroeconomic Data in a SAM

Macroeconomic data provide a summary description of a nation's economic activity. Some of the row sums and column sums of the SAM are macroeconomic indicators. For example, the column sum of the private household account reports an economy's total private consumption expenditure, and the row sum of the ROW account reports total imports of goods and services. We can also aggregate other microeconomic data in the SAM to calculate descriptive macroeconomic statistics, such as the gross domestic product (GDP). Developing macroeconomic indicators from the data in a SAM is a useful exercise because it illustrates how the macroeconomic behavior of an economy rests on the microeconomic behavior of firms and households. (Text Box 3.3 provides an interesting example of a group of modelers who work in the opposite direction. In their research, they impose long-run growth projections for macroeconomic variables, such as the labor force, as an experiment, and then solve for the resulting microeconomic structure of the economy.)

Text Box 3.3. Macroeconomic Projections in a CGE Model of China
"China in 2005: Implications for the Rest of the World." (Arndt, et al. 1997).

What is the research question? In 1992, the Chinese economy was projected to triple in size over the next thirteen years. How will China's rapid growth affect its competing exporters in world trade and its import suppliers?

What is the CGE model innovation? The authors simulate the projected growth rates in macroeconomic variables (population, capital stock, and productivity) and analyze the resulting effects on the microeconomic composition of industry supply, demand, and trade in fifteen regions, including China, in the GTAP CGE model. The authors also carry out a systematic analysis of the sensitivity of their results to alternative values of import substitution elasticities, and they decompose welfare effects using the GTAP welfare decomposition utility.

What is the experiment? The experiment imposes cumulative projected growth rates of macroeconomic variables. The results describe the level and microeconomic structure of the fifteen economies in 2005. An alternative experiment assumes a lower growth rate of Chinese factor endowments that eliminates growth in its per capita GDP. The results of this alternative scenario for 2005 are deducted from those of the first scenario to identify the effects of China's rapid economic growth.

What are the key findings? Based on net-trade positions and likely changes in world prices, China's growth has an adverse impact on other developing countries. However, from a broader perspective that considers terms-of-trade benefits, efficiency gains, and factor endowment effects, China's growth benefits twelve of the other fourteen regions in the model, a result that is robust to a wide distribution of assumed trade elasticity values.

In the following examples, we use microeconomic data from the U.S. 3x3 SAM to calculate three important macroeconomic indicators: GDP from the income and expenditure sides, and the savings-investment balance.

GDP from the Income Side

GDP from the income side reports the sources of total national income from (1) the wages and rents that production activities pay to the factors (e.g., labor and capital) that they employ (reported on a net, or after-income tax, basis), and (2) total tax revenues in the economy:

$$\text{GDP} = \text{Factor income} + \text{tax revenue}$$

We calculate this macroeconomic indicator using data from the U.S. SAM's row accounts, which report income flows:

Factor payments = 8,106 =

Land factor payments: 34

Labor factor payments: 68 + 1,109 + 5,667 = 6,844

Capital factor payments: 122 + 467 + 2,332 = 2,921

Minus income taxes: 3 + 1,446 + 244 = 1,693

Plus taxes = 3,570 =

Import tariffs: 1 + 24 = 25

Export taxes: 2

Sales taxes on imported variety: 1 + 47 + 0 = 48 (from sales tax row totals)

Sales taxes on domestic variety: 2 + 178 + 45 = 225 (from sales tax row totals)

Factor use taxes: − 3 + 1, 021 + 90 = 1, 108 (from factor use tax row totals)

Production taxes: 4 + 42 + 43 = 469

Income taxes: 3 + 1,446 + 244 = 1,693

Thus, U.S. GDP from the income side is:

$$\text{GDP} = 8{,}106 + 3{,}570 = 11{,}673 \text{ billion (adjusted for rounding)}$$

GDP from the Expenditure Side

GDP from the expenditure side is a macroeconomic indicator that reports the allocation of national income across four aggregate categories of final demand: private household consumption expenditure, C, investment expenditure, I, government consumption expenditure, G, and net exports, E–M. You may recall this important equation, called the national income identity equation, from your macroeconomics studies:

$$\text{GDP} = \text{C} + \text{I} + \text{G} + (\text{E-M})$$

We calculate GDP from the expenditure side using data from the U.S. SAM's column accounts, which report expenditure flows:

$$\begin{aligned} \text{C} &= \text{demand for commodities} + \text{sales taxes} \\ &= \text{total private consumptionexpenditure} \end{aligned}$$

$$\begin{aligned} \text{C} &= (9 + 415 + 60 + 60 + 1,104 + 6{,}392) + (1 + 35 + 0 + 2 + 115 + 41) \\ &= 8{,}233 \end{aligned}$$

Text Box 3.4. Distributing National Effects to the State-Level in a CGE Model of the United States
"Disaggregation of Results from a Detailed General Equilibrium Model of the U.S. to the State Level." (Dixon, Rimmer and Tsigas, 2007)

What is the research question? The USAGE-ITC, developed at the U.S. International Trade Commission, is a recursive dynamic CGE model descended from the Monash and ORANI models of Australia. It has more than 500 U.S. industries and multiple U.S. trade partners. However, U.S. policymakers are often concerned with the impacts of national policies at the state level. Can an already large, national-level model be solved to also yield results for state-level variables?

What is the CGE model innovation? The authors develop a "top-down" approach to disaggregating national results to the state level. First, a static version of the CGE model is used to solve for variables at the national level, including employment, private and government consumption, trade, real GDP, and industry output and employment. Then, state-level results are computed using an "add-in" program. The program describes the impacts for each state as the change in the national-level variable plus a state-specific deviation term. This approach ensures that state-level impacts sum to the national level, however results at the state-level do not feed back to affect national-level variables.

What is the model experiment? The authors test their approach using an illustrative experiment in which the United States removes all import tariffs and quotas.

What are the key findings? The authors focus on employment effects, concluding that differential employment impacts across states reflect not only the shares of industries in employment in each state, but also states' proximities to ports and to other high- or low-growth states.

$$\mathrm{I} = \text{demand for commodities} + \text{sales taxes} = \text{total investment expenditure}$$

$$\mathrm{I} = (0 + 237 + 3 + 0 + 628 + 1{,}315) + (0 + 5 + 0 + 0 + 10 + 1) = 2{,}198$$

$$\mathrm{G} = \text{demand for commodities} = \text{total government consumption expenditure (governments usually don't pay tax)}$$

$$\mathrm{G} = (0 + 1 + 1 + 1 + 2 + 1{,}805) = 1{,}810$$

The trade margin costs incurred in shipping goods to an importing country raises the costs of its imports. These margins are therefore included when calculating expenditures on imports. On the export side, a country's sale of the trade margin services used in global shipping is an export of a type of service so, just like the export of any product, these sales are included in the value of its total exports. The GDP calculation excludes import tariffs and export taxes, however, because these are already embedded in the values of exports and imports reported in the final demand columns of the SAM.

$$E = \text{exports} + \text{exports of trade margins}$$
$$E = (50 + 756 + 259) + 24 = 1{,}089$$
$$M = \text{imports} + \text{trade margins on imports}$$
$$M = (167 + 1{,}203 + 230) + (9 + 47 + 0) = 1{,}657$$

Thus, U.S. GDP from the expenditure side is:

$$GDP = 8{,}233 + 2{,}198 + 1{,}810 + (1{,}089 - 1{,}657) = \$11{,}673 \text{ billion.}$$

Savings-Investment and the Balance of Trade

Recall from your macroeconomic coursework that by rearranging the expression for GDP from the expenditure side, we can derive this macroeconomic identity equation to describe the relationship between a nation's *domestic* savings, S_D, its investment spending net of depreciation, I_N, and its trade balance, $E - M$:

$$S_D - I_N = E - M$$

We can use data from the SAM to calculate the balance of trade and the savings-investment balance, and check that this relationship holds true in the U.S. 3x3 SAM, where:

S_D = domestic savings = 585, and

I_N = Investment spending minus depreciation = 2,198 − 1,046 = −\$1,152

and E and M are already known from our calculation of GDP from the expenditure side. Thus, we can verify that in our database, the gap between domestic savings and net investment equals the trade deficit:

$$585 - 1{,}152 \text{ (adjusted for rounding)} = 1{,}089 - 1{,}657 = -\$568 \text{ billion}$$

Structure Table

As a SAM's dimensions become larger, with an increased number of industries, factors, household types, or taxes, it becomes more challenging to fully understand or describe the complex economy that it depicts. (See Text box 3.4.) One way to develop an overview of an economy without losing the detailed information available in the SAM is to construct a ***structure table***. The table uses the microeconomic data in the SAM to describe the economy in terms of shares. For example, it reports the shares of each commodity in households' total consumption and the shares of each commodity in a country's total exports. Share data will enable you to make quick comparisons and to identify the most important features of the economy that you are studying.

You are likely to find yourself often referring to your structure table as you define experiments and interpret your model results.

Table 3.3 presents an illustrative structure table constructed from the data in the U.S. 3x3 SAM. We can use the structure table to make observations like these about the U.S. economy:

- The United States now has a service economy. Services account for 81 percent of GDP, 83 percent of labor employment and 79 percent of household spending.
- U.S. agriculture is a "capital-intensive" industry; capital accounts for a larger share (54 percent) of its factor costs than labor or land, and the capital share in factor costs is higher in agriculture than in other industries.
- U.S. manufacturing and services production are relatively "labor-intensive." The industries spend far more on labor (73 percent) than on capital inputs, and labor's share in their factor costs is higher than in agriculture.
- The United States imports more than 30 percent of its food supply but households spend only 1 percent of their budget on food.
- Trade is very important to U.S. manufacturing – imports account for 22 percent of U.S. consumption of manufactured goods, and exports for 14 percent of manufacturing output

You can follow the steps described below to construct a structure table for the country that you are studying. We demonstrate how each type of indicator is constructed, using data from the U.S. 3x3 SAM as an example, and we explain how each indicator can be useful as you begin to run model experiments and interpret your results.

Industry GDP

The GDP for industry *a* is calculated from the SAM's activity and tax column accounts as:

Factor payments by a + taxes on factor use, output, sales, and trade of a

Using agriculture as an example, we can calculate the GDP for U.S. agriculture from data in the U.S. 3x3 SAM as:

Agricultural factor payments = 34 + 68 + 122 = 224
Agricultural taxes = 3
Factor use taxes in agriculture = −3 + 5 −1 = 1
Sales taxes paid by agricultural activity on imported inputs = 0
Sales taxes paid by agricultural activity on domestic inputs = −1 −1 −4 = −6
Production tax on agricultural activity = 4
Import tariffs on agriculture = 1
Export taxes on agriculture = 0
Sales tax on final demand for imported and domestic agriculture = 1 + 2 = 3
Agricultural GDP = 224 + 3 = 226 (adjusted for rounding)

Table 3.3. *Structure Table for the United States in 2004*

	Industry GDP $US billion	Industry Shares in GDP	Factor Shares in Industry Factor Costs			Industry Shares in Factor Employment		
			Land	Labor	Capital	Land	Labor	Capital
Agriculture	226	2	14	32	54	100	1	4
Manufacturing	2,007	17	0	73	27	0	16	16
Services	9,441	81	0	73	27	0	83	80
Total	11,673	100	na	na	na	100	100	100

	Commodity shares in:							
	Domestic Demand				Trade			
	Intermediate Demand	Private Household Consumption	Government Consumption	Investment Demand	Exports	Imports	Import Share of Domestic Consumption	Export Share of Domestic Production
Agriculture	5	1	0	0	5	11	32	12
Manufacturing	37	20	0	40	69	75	22	14
Services	58	79	100	60	26	14	2	2
Total	100	100	100	100	100	100	8	5

Source: GTAP v.7.0 U.S. 3x3 database.

Industry Share in GDP

The share of industry a in total GDP is calculated as:

$$\text{Industry } a\text{'s GDP/ GDP} * 100$$

The share of U.S. agriculture in GDP is therefore:

$$226/11{,}673 * 100 = 2$$

The relative size of an industry in total GDP is among its most important economic characteristics. The larger its size relative to other industries, the greater is the impact of a shock in that industry on the rest of the economy. Given the small size of agriculture in the U.S. economy, do you think that a policy shock, such as the removal of agricultural production subsidies, would have significant effects on the U.S. economy as a whole? Probably not, although it may be a difficult shock to absorb for those engaged in agriculture.

Factor Shares in Industry Factor Cost

Factor cost shares describe which factors are most important in an industry's total factor costs. For example, capital equipment such as drills and pumps typically account for a far larger share of the factor costs of the petroleum extraction industry than labor. Factor cost shares are calculated for each factor f for each industry a from data in the production activity column accounts. An industry's factor costs include the wages and rents that it pays directly to each factor plus factor use taxes such as Social Security:

(factor payment plus factor use tax for factor f in industry a)/total factor cost in industry a * 100

As an example, we calculate the factor cost share for labor employed in the U.S. manufacturing industry as:

Labor cost share in mfg. = labor payment plus labor use tax in mfg./ total factor cost in mfg. * 100

$$(1{,}109 + 166)/(1{,}109 + 467 + 166 + 15) * 100 = 73$$

Thus, labor accounts for 73 percent of factor costs in U.S. manufacturing.

Factor cost shares in an industry matter when there are shocks that change the relative price or the productivity of a factor. For example, consider an industry such as wearing apparel, which spends far more on wages than it does on capital equipment. If there is an increase in the labor supply that causes wages to fall, then the apparel industry's factor costs will fall by proportionately more than in the petroleum extraction industry, from our previous example. The apparel industry's proportionately larger factor cost savings are likely to lead to an increase in its output and in its size relative to the petroleum industry, depending on consumer demand.

Industry Shares in Factor Employment

Industry shares in factor employment describe where an economy's land, labor, and capital endowments are employed. The shares are calculated for factor *f* and industry *a* from the income data in the factor rows of the SAM:[4]

Factor payment to factor f in industry a/sum of factor payments to f by all industries * 100

Using data from the U.S. 3x3 SAM, we calculate industry employment shares for labor as:

Labor payment in agriculture/sum of activity payments to labor $68/(68 + 1{,}109 + 5{,}667) * 100 = 1$

Labor payment in manufacturing/sum of activity payments to labor $1{,}109/(68 + 1{,}109 + 5{,}667) * 100 = 16$

Labor payment in services/sum of activity payments to labor $5{,}667/(68 + 1{,}109 + 5{,}667) * 100 = 83$

Most U.S. labor is employed in services (83 percent) and just 1 percent is employed in agriculture.

Industry shares in factor employment are useful to know because the larger an industry's employment share, the larger is the impact on the economywide wage and rent when there is a change in its production and factor demand. For example, with 83 percent of U.S. labor employed in the service sector, a decline in the production of services would likely have a larger effect on national employment and wages than would a decline of similar proportion in agricultural output. Less employment in services could cause the average U.S. wage to fall because the loss of even a small proportion of service jobs means that a relatively large share of the U.S. work force must look for new employment.

[4] Most CGE models include data on the value of factor payments or earnings, but not factor quantities, such as number of workers or acres of land. We can only infer industry shares in employment from income data if we assume that all workers and all capital equipment receive the same wages and rents across all industries. In this case, each dollar that any production activity pays to a factor buys the same factor quantity. This is the simplifying assumption made in many CGE models. However, wages and rents are often observed to differ across industries. Many doctors, for instance, earn more per hour than programmers. In this case, two production activities may pay the same amount of wages and rents, but employ different quantities of workers and equipment. Some CGE models account for wage or rent differentials across industries, but their databases must also include factor quantity data.

Commodity Shares in Domestic Demand

Firms, private households, government, and investors usually demand different types of goods and services. For instance, all households purchase food while investors rarely buy food and instead purchase mostly heavy machinery and equipment for use in factories and other businesses. The shares of each commodity *i* (which includes domestic and imported varieties) in total spending by each agent *d* describe an economy's consumption patterns. Because sales taxes are part of the purchase price, the calculation of commodity shares also includes that tax.

Commodity shares for each agent and commodity are calculated from the spending data reported in the agents' columns in the SAM:

Expenditure by agent *d* on commodity *i* plus sales taxes/total consumption expenditure by agent *d* * 100

Using private household spending on the manufactured commodity as an example, the share of the manufactured commodity in total private household spending is calculated as:

$$(415 + 1{,}104 + 35 + 115)/8{,}233 * 100 = 20$$

When consumption patterns differ among agents, the same shock can affect each of them in different ways. For example, if the same sales tax is levied on all private sector purchases of services, the impact on households will be proportionately greater than on investors, because households consume more services than investors, as a share of their spending. Alternatively, taxes may be levied in a targeted way based on consumption shares. For example, a tax code may be designed to impose higher sales taxes on the types of goods that are purchased mainly by businesses, or by high-income households.

Commodity Shares in Exports and Imports

Commodity shares in the value of total exports and total imports describe the commodity composition of trade. The shares of each commodity *i* in total exports are calculated from data in the SAM's column accounts for export margins and the rest-of-world. The export margins are included because margins are a type of service export. Export taxes are excluded because they are already embedded in the export value reported in the commodity row of the SAM:

export of *c*/total commodity exports plus total margin exports * 100

Using manufacturing as an example, and data from the U.S. 3x3 SAM, the share of manufacturing in total exports is:

$$756/(24 + 50 + 756 + 259) * 100 = 69$$

Thus, manufactured products account for most of U.S. exports of goods and services.

The share of each commodity *i* in the value of total imports is calculated using data from the column accounts of the imported variety of each commodity. The value of imports is inclusive of trade margins, but excludes import tariffs:

Import plus trade margin on import of commodity *i* /
total commodity imports plus total trade margins on imports * 100

Using agriculture in the United States as an example, its share in total U.S. imports is:

$$(9 + 167)/(9 + 167 + 47 + 1{,}203 + 230) * 100 = 11$$

Import Share of Domestic Consumption

The share of imports in the total value of total consumption of commodity *i* by firms, private households, government, and investors combined, determines the strength of the linkage between events in world markets and domestic consumers. Consider the effect of an increase in world oil prices. Countries that depend on imports for a large share of their domestic petroleum consumption will experience a greater shock to their economy than would countries that import very little oil. Calculating import shares of consumption must take into account the sales taxes paid on both varieties of commodity c.

The import share of consumption of commodity *i* is calculated as:

Total domestic demand plus sales tax for the imported variety of *c*/total domestic demand plus sales taxes for imported plus domestic varieties of commodity *c* * 100.

Using U.S. manufacturing from the U.S. 3x3 SAM as an example, the import share in domestic consumption of the manufactured commodity is calculated from data in the commodity rows and sales tax rows:

Total domestic demand for imports of mfgs. = 629 + 450 + 1 + 242 = 1,322

where:

Intermediate demand for mfg. import = (12 + 393 + 216) + (0 + 3 + 5) = 629
Private household demand for mfg. import = 415 + 35 = 450
Government demand for mfg. import = 1
Investment demand for mfg. import = 237 + 5 = 242.

We leave it as an exercise for you to verify that the value of total domestic consumption of the manufactured commodity (imported plus domestic varieties) = 5,972. The import share of domestic consumption of manufactured goods is therefore:

$$1{,}322/5{,}972 * 100 = 22$$

Given a 22 percent share of imports in U.S. consumption of manufacturing, what do you think would happen if a foreign export tax causes the price of manufactured imports by the United States to rise sharply? The effect will probably be significant (and negative) because imports constitute a large part of aggregate U.S. demand for manufactures.

Export Share of Production

Similar to the case of imports, the share of exports in the total value of production of good *i* determines the strength of the linkage between world markets and domestic producers. Because the revenue that producers get from export sales includes export taxes (or subsidies), the calculation of the export share of production also includes that payment. Export margins are not included as a cost to exporters, since these freight and insurance charges are assumed to be paid by importers. The export share of production of each good or service is calculated from data in the domestic commodity row, and the rest-of-world column in the SAM:

(Exports of good *i*)/Domestic sales of *i* * 100.

Using U.S. agriculture as an example, we calculate the export share of production as:

$$(50)/434 * 100 = 12$$

Because U.S. farmers export 12 percent of their output, how do you think they are likely to be affected by a foreign import subsidy and a resulting increase in foreign demand? Because exports do not represent a very large share of U.S. production, the impact is likely to be positive but rather small.

Tax Data in a SAM

Import tariffs and taxes on exports, sales, production, and factor use, all drive a wedge between the prices received by sellers and the prices paid by buyers. Income taxes effectively reduce the wage and rents earned by labor, capital, and other factors of production. The tax data in the SAM report the value of taxes paid by each agent and the total amount of tax revenue generated by each tax in the model. The location of tax data in the cells of the SAM reveal the economic activity on which each tax is levied.

Developing a ***tax structure table*** using the tax data in the SAM will enable you to gain an overall perspective on the importance of these policies in the economy that you are studying. A tax structure table expresses the tax flow data in terms of tax rates. For example, if the SAM reports that consumers pay ten cents in import tariffs on the import of $1 of textiles, then the tax structure table will report a 10 percent import tariff rate on textiles (since 10 cents/$1 * 100 = 10 percent).

Many of your experiments will entail changes in tax and tariff rates. The tax structure table provides a foundation for your analysis that helps you to define your experiments and interpret your model results. For example, if all else is equal, the removal of a tax with a high initial rate is likely to have a larger effect on quantities in the model than removal of a tax with a low rate. A tax structure table also facilitates a comparison of your model and results with those of other researchers.

We describe in Chapter 8 how to calculate each type of tax and subsidy rate using data in the SAM. For now, we simply present a tax structure table based on data from the U.S. 3x3 SAM, as an example (Table 3.4).

The SAM and Economic Models

The SAM framework was developed to support economic models of national income and spending. The models were not initially CGE models, but **multiplier models**, used for economywide economic planning and the analysis of linkages between an economy's industry structure and the distribution of income across different types of households.[5] The modelers developed the SAM framework as a way to organize and display national accounts data in a format that depicts the circular flow of income and spending that interconnects all parts of an economy.

A key contribution made by multiplier models is their ability to calculate the direct and indirect effects of an economic shock on the quantities of supply and demand in an economy. The direct effect is the change in the economic activity that is shocked. For example, the direct effect of a tax on auto production may be to reduce auto output by ten cars. The indirect effects are the changes in related activities that occur because industries rely on other industries to supply their inputs or buy their outputs, and because a change in output of any industry leads to changes in employment, incomes

[5] See Pyatt and Round (1985) for a discussion of the development of SAMs in the Cambridge Growth Project and their use in multiplier models. Breisinger, Thomas, and Thurlow (2009) provide excellent and intuitive instructions for developing a multiplier model using a SAM.

Table 3.4. *Tax Structure Table for the United States, 2004*

	Tax Rate and Agent that Pays the Tax							
Type of Tax	Agriculture	Manufacturing	Services	Private Households	Investment	Land	Labor	Capital
	Commodity accounts							
Import tariff								
Agriculture	0.48	0.48	0.48					
Manufacturing	1.91	1.91	1.91					
Services	0.00	0.00	0.00					
Export tax	0.01	0.29	0.00					
	Production activities							
Sales tax – imports								
Agriculture	–4.10	0.01	0.02	6.38	0.00			
Manufacturing	–2.01	0.67	2.25	8.49	1.91			
Services	–2.82	0.00	0.00	0.02	0.00			
Sales tax – domestic								
Agriculture	–4.02	0.00	0.05	4.07	0.00			
Manufacturing	–0.99	0.73	3.69	10.40	1.61			
Services	–3.73	0.27	0.12	0.44	0.05			
Factor use tax								
Land	–9.48	0.00	0.00					
Labor	7.19	15.00	15.00					
Capital	–1.05	3.253	3.25					
Production tax	1.00	0.80	2.83					
Income tax						8.35	21.13	8.35

Notes: Positive rate denotes a tax; a negative rate denotes a subsidy.
Source: GTAP v.7.0 U.S. 3x3 database.

and taxes, and final demand. For example, if, according to the SAM, each car requires four tires, then automakers will reduce their demand for tires by forty. An indirect effect is the reduction in tire output and the employment of tire workers, based on the number of workers required per tire as described in the SAM. In addition, the loss of employment for auto and tire workers will reduce household incomes and demand for items such as clothing and restaurant meals, thereby leading to indirect effects on the apparel and food service industries, too.

Multiplier models essentially trace the effects of an exogenous shock in one or more parts of the SAM throughout the rest of the SAM as an accounting procedure. Producers adjust the quantity of their output to meet any changes in demand and consumers adjust their demand in response to any change in income. Prices are fixed and there are no limits on the supply of labor, capital or other productive resources.

The multiplier, similar to the fiscal multiplier you may have studied in macroeconomics, calculates the sum of successively smaller rounds of adjustment to a shock until the economy is again in equilibrium. In our example, the decline in income to workers in the auto and tire industries will reduce their demand for all types of goods, including autos, leading back to a further decline in auto production, perhaps by two autos. This reduces automakers' demand for tires by eight, causing incomes and demand to fall again, and so on, until the size of successive adjustments fall to zero.

CGE models represent the next generation of economywide models because they describe changes throughout the SAM as the result of producers maximizing their efficiency and consumers maximizing their utility. Productive resources are in limited supply and firms' competition for them will affect their prices. Instead of a multiplier process, the CGE model solves for a new set of prices at which supply and demand are again in equilibrium, based on the optimizing behavior of producers and consumers. Each cell in the SAM matrix therefore corresponds to an economic equation in the CGE model. In the chapters that follow, we reinforce this connection between the SAM database and optimizing behavior in the CGE model by prefacing our study of the economic behavior in each part of the CGE model with a description of the corresponding data in the SAM.

Summary

In this chapter, we described the SAM, a logical format used to organize and display CGE models' databases as a circular flow of income and spending in an economy. The SAM is a square matrix because each of its accounts is described by both a row, which records income, and a column, which describes spending. Each cell of the SAM describes a transaction simultaneously as an expenditure by a column account and as an income source to a row account. A SAM is balanced when the total income for each account (its row total) is equal to its total spending (its column total). A balanced SAM describes an economy in equilibrium. The accounts and the location of data in the cells of the matrix vary among SAMs because a SAM corresponds to the structure and theory of the CGE model in which it is used. Using a three-industry, three-factor SAM for the United States in 2004 as an example, we calculated macroeconomic indicators and developed a structure table and tax table. These tables are a useful way to summarize the microeconomic data in the SAM and they inform experiment design and the analysis of model results.

Key Terms

Activity
Agent
Commodity
Factor of production
GDP from the income side
GDP from the expenditure side
Gross value of output
Intermediate input
Regional household
Trade margin
Social Accounting Matrix
Structure table
Tax structure table
Value added

PRACTICE AND REVIEW

1. Based on data in the manufacturing activity column in the U.S. 3x3 SAM:
   a. What is the gross output of the manufacturing activity?
   b. What is the total value of the intermediate inputs used in the production of manufacturing, including sales taxes? Which intermediate input accounts for the largest share of input costs, including sales taxes? Calculate its cost share.
   c. What is the total value of taxes paid by the manufacturing production activity? On which input is the tax payment largest?
   d. Based on Table 3.4, on which factor input in manufacturing is the tax rate highest?
2. Based on data in the manufacturing commodity column in the U.S. 3x3 SAM:
   a. What is the value of the imported supply of the manufactured commodity (including import tariff and import margin)?
   b. What is the value of the supply from the domestic variety (including export taxes)?

   c. What is the total, or aggregate, supply of the manufactured commodity in the United States?
3. Based on data in the manufacturing commodity rows in the U.S. 3x3 SAM:
   a. Where is the imported variety of the manufactured commodity sold? List each sale and calculate the value of total sales.
   b. Where is the domestic variety of the manufactured commodity sold? List each sale and calculate the value of total sales.
   c. Accounts in a SAM are balanced when supply or income (the row total) is equal to demand or spending (the column total). Are the supplies of the imported and the domestic manufactured commodities equal to the value of their sales? Check the rest of the accounts in the SAM. Are all of the accounts in the SAM balanced?
4. Based on data for the services production activity in the U.S. 3x3 SAM:
   a. Which factor has the largest cost share in the production of services? Show your calculations.
   b. What is the amount of services' production tax? Is output taxed or subsidized?