4

Final Demand in a CGE Model

In this chapter, we describe final demand by domestic agents – private households, government, investors – and by the export market. Data in the Social Accounting Matrix (SAM) describe agents' incomes and the commodity composition of their spending. The computable general equilibrium (CGE) model depicts demand by domestic agents as a two-stage decision. First, consumers decide on the quantities of each commodity in their consumption basket. Second, an "Armington" import aggregation function describes their choice between domestic and imported varieties of each commodity. We survey functional forms commonly used in CGE models to describe private household preferences. We also introduce the concept of "national welfare," which is the monetary value of changes in a nation's well-being following an economic shock.

The U.S. economic stimulus package, implemented in the 2009 recession, was designed to increase government spending in order to compensate for sharp declines in spending by private households and investors, and in export sales. These four categories of demand – private households, investment, government, and exports – constitute the demand side of an economy. They are called components of ***final demand*** since the goods and services that are consumed are in their end-use; they are not further combined or processed into other goods and services. An economy's structure can change when the categories of aggregate final demand change in relative size because each type of final demand usually purchases different goods and services. For example, households purchase items like groceries and entertainment, whereas investors purchase mainly machinery and equipment, and governments mostly purchase services. The increased share of the government in U.S. final demand as a result of the stimulus program is thus likely to change the types of goods demanded in the U.S. economy, at least in the short term.

In this chapter, we learn how the SAM's data describe each component of final demand. We then study how each final demand agent is assumed to behave in the CGE model. Our discussion in this chapter mostly focuses

Table 4.1. *Final Demand Data in The U.S. 3x3 SAM ($U.S. Billions)*

	Private Household	Government	Savings-Investment	Trade Margin Export	Rest-of-World
Imports					
Agriculture	9	0	0	0	0
Manufacturing	415	1	237	0	0
Services	60	1	3	0	0
Domestic					
Agriculture	60	1	0	0	50
Manufacturing	1,104	2	628	0	756
Services	6,392	1,805	1,315	24	259
Sales taxes–imports					
Agriculture	1	0	0	0	0
Manufacturing	35	0	5	0	0
Services	0	0	0	0	0
Sales tax–domestic					
Agriculture	2	0	0	0	0
Manufacturing	115	0	10	0	0
Services	41	0	1	0	0
Savings–Investment	0	0	0	32	536
Total	8,233	1,810	2,198	56	1,601

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

on commonalities among CGE models, including the concept of "commodities," the two- (or three-) stage budgeting decision and the measurement of national welfare. CGE models differ widely in their descriptions of private households' consumption behavior, making it difficult to characterize a "standard" CGE model in this respect. Thus, we survey four functional forms commonly used in CGE models to describe private households' preferences, and we explain the differences among these functions that are of practical importance for the modeler.

Final Demand Data in a SAM

Table 4.1 presents data on final demand from the U.S. 3x3 SAM. The table reproduces the column accounts (omitting the rows with zeros) that record expenditures by domestic consumers – which include private households, government, and investors – and by the rest of world.

Consumers demand commodities, such as "agriculture," which are composed of the domestic and imported varieties of a good. In the U.S. 3x3 SAM, consumers' column accounts separately record their spending on the imported and domestic variety of each of the three commodities (agriculture, manufacturing, and services). For example, U.S. private households spend a total of \$69 billion on the agricultural commodity, composed of \$9 billion worth of imported agricultural goods and \$60 billion of the domestic variety. Private households also spend \$1 billion on retail sales taxes on the imported variety and \$2 billion on retail sales taxes on the domestic variety. The total value of private household expenditure on all commodities, including sales taxes, is \$8,233 billion. The column accounts for the U.S. government and investors similarly report their total spending on commodities plus sales taxes.

The export trade margin's column account reports U.S. exports of insurance and freight (*cif*) services used in global trade. Expenditures reported in the rest-of-world's column account report foreign purchases of U.S. goods, which are valued in U.S. *fob* export prices (i.e., excluding trade margin charges). Both of these column accounts include, in addition, payments to the savings-investment row account. The payments report the balance of trade in margin services and in other goods and services. A positive value indicates a foreign exchange inflow (a balance of trade deficit), and a negative value indicates a foreign exchange outflow (a balance of trade surplus). In the U.S. SAM, the positive numbers signal that the United States has trade deficits in both trade margin services, and in goods and services, which sum to \$568 billion.

We can use the final demand data in the SAM to calculate ***budget shares***. A budget share is the share of a commodity in the consumer's total spending. For example, private households' spending on imported manufactured goods (including the sales tax) accounts for 5.5 percent of their total spending.

Income Data in a SAM

CGE models impose the constraint that spending on goods and services, taxes and savings must equal income. You may recognize this model constraint from your microeconomic theory, in which spending is subject to a budget constraint. Indeed, you may recognize this constraint from managing your own finances, as you decide how to allocate your after-tax income to purchases and to savings. Because final demand is constrained by income in the CGE model, it is worthwhile also to examine the income data in a SAM.

Data in Table 4.2 report the row accounts from the U.S. 3x3 SAM that describe income flows. Income originates from the employment of factors by production activities. The land factor, for example, earns a total of \$34 billion, paid from the activity columns to the land factor row. Of this amount, the land column account reports that \$3 billion is spent on land-based income taxes and the remaining, after-tax income of \$31 billion is paid to the regional

Table 4.2. *Income Flows in The U.S. 3x3 SAM ($U.S. Billions)*

	Total Production Activities	Land	Labor	Capital	Income Tax	All Other Taxes	Regional Household
Land	34						
Labor	6,844						
Capital	2,921						
Income tax		3	1,446	244			
All other taxes	1,639						
Regional household		31	5,397	1,632	1,693	1,875	
Private household							8,233
Government							1,810
Savings–investment				1,046			585
Total	11,438	34	6,844	2,921	1,693	1,875	10,628

Note: The production activities' column sums the agriculture, manufacturing, and services activities columns of the U.S. 3x3 SAM.
Source: GTAP v.7.0 U.S. 3x3 database.

household's row account. Labor earnings of $6,844 billion are also divided between income taxes and payments to the regional household. Capital earnings of $2,921 billion are paid to income taxes and the regional household and, in addition, are expended on savings (this payment measures the depreciation of capital equipment and machinery).

The regional household's row account shows its accumulation of $7,060 billion in after-tax factor income ($31 plus $5,397 plus $1,632 billion), income taxes ($1,693 billion), and all other taxes combined ($1,895 billion). National income, excluding depreciation, therefore totals $10,628 billion. National income is then allocated by the regional household's column account to the three categories of domestic spending: Private households receive (and spend) $8,233 billion, the government receives (and spends) $1,810 billion, and $585 billion is saved (this includes combined household savings and government savings).[1]

Two-Stage Domestic Final Demand

In most CGE models, domestic consumers make their consumption decision in two stages, depicted in Figure 4.1. In the first stage, shown at the top level in the figure, they decide on the quantity of each commodity in their

[1] In the GTAP model that corresponds to this SAM, the allocation of regional household income is determined by a demand system that allows the shares of private households, government, and savings in national income to change. In most CGE models without a regional household account, private household income is equal to factor income, government income is equal to tax revenues, and investment spending is equal to savings.

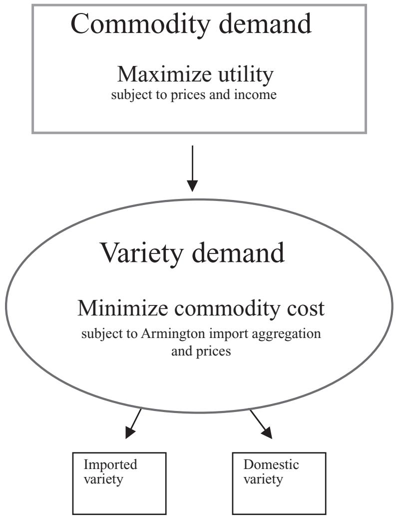

Figure 4.1. Two-stage domestic final demand

consumption basket, such as the amount of food and the number of books. Their choice depends upon their subjective preferences. For example, consumers may prefer a large quantity of food relative to books. These preferences are described by a ***utility function***, an equation that quantifies how much utility, or satisfaction, consumers derive from any given combination of consumption goods. Given their utility function, consumers select the basket of goods that generates the maximum achievable satisfaction given the prices of the goods and their budgets.

In the next stage, consumers minimize the cost of their commodity bundle by deciding on the shares of domestic and imported varieties that comprise each commodity. For example, once a consumer has decided on the quantity of food in her basket, she next decides on the amounts of domestically produced or imported food that she prefers, given their relative prices. This decision is governed by an ***Armington import aggregation function***, named after the economist Paul Armington (1969), who developed this type of sourcing decision in an applied economic model.

Some CGE models have an additional stage that describes the lowest-cost sourcing of imports from alternative suppliers for a given quantity of a commodity import. For example, once the consumer decides on the quantity of imported shoes that he prefers, he then chooses the least-cost bundle of imported shoes from competing suppliers, such as Italy or Japan. Since this additional stage in consumer decision making is identical to that between the aggregate import and the domestic variety, for brevity, we omit further discussion of it. (See Text Box 4.1 for another example of an additional stage

Text Box 4.1. Consumer Aversion to GM Foods
"Genetically Modified Foods, Trade and Developing Countries."
(Nielson, Thierfelder, and Robinson, 2001).

What is the research question? Genetically modified (GM) seeds used in agricultural production have raised yields and increased pest resistance. Their use lowers production expenses by reducing the need for costly chemical and fertilizer inputs. However, some consumers, especially in developed countries, are concerned about the possible, unknown health effects of GM foods and prefer not to purchase them. How might consumer aversion to GM foods affect developing countries that produce and export these crops?

What is the CGE model innovation? The authors develop a database on trade and production of GM crops that they use to disaggregate the rows and columns of the SAMs' activity and commodity accounts for grains and oilseeds into GM and non-GM varieties. They also introduce an additional stage of the consumer budget allocation decision into an eight-region, global version of the International Food Policy Research Institute (IFPRI) standard CGE model. At the top level, a Cobb-Douglas utility function describes consumers as spending a fixed share of their budgets on grain and oilseed commodities. At the second level, a CES utility function describes consumers' choice between the GM and non-GM varieties of each commodity.

What is the model experiment? GM adoption is described as a 10 percent increase in total factor productivity and a 30 percent reduction in the use of chemical intermediate inputs in the GM grains and oilseed sectors. The authors present two alternative approaches to describe the aversion to GM foods by consumers in developed countries. First, they assume that consumers become less sensitive to prices, which is modeled as a reduction in the substitution elasticity between GM and non-GM varieties. Second, they assume a structural shift in demand by imposing a very low, fixed 2 percent budget share parameter for the GM variety. They reduce the share parameter by changing the base data in the SAMs and recalibrating the model.

What are the key findings? Adoption of GM crops provides farmers in developing countries with productivity benefits that lead to large welfare gains. Consumer preferences in developed countries do not diminish these gains since bilateral trade patterns adjust, and GM and non-GM products are redirected according to preferences in the different markets.

in consumer decision making; in this case related to the genetic attributes of food products.)

Most of our discussion in this chapter describes the utility-maximizing behavior of private households at the first stage of their consumption decision. We treat this stage of government and investment demand for commodities very briefly since many CGE models describe their preferences in a

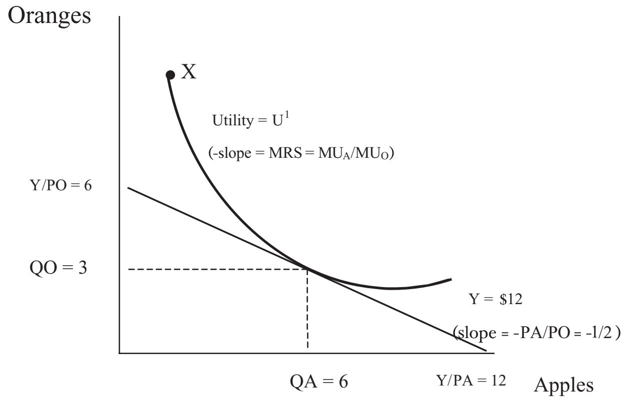

Figure 4.2. Consumer utility function with a budget constraint

simple fashion, by assuming that the initial budget shares in their consumption baskets remain fixed.[2] For example, if the government spends 10 percent of its budget on agricultural commodities, it will continue to spend 10 percent of any sized budget on agricultural commodities. Or, if agricultural prices rise by 10 percent, the government will reduce the quantity of agricultural goods that it purchases by 10 percent so that the agricultural budget share remains constant. This simple specification of government spending reflects the view that economic theory does not fully explain government outlays. In the case of investment, the standard, one-period CGE model that we are studying does not account for intertemporal calculations or expectations about the future that influence today's investment decisions. Consequently, this fixed-share allocation rule for investment demand is a transparent approach that simply replicates the demand for capital goods observed in the model's base year and reported in the SAM.

Utility-Maximizing Private Households

Private households in CGE models are assumed to be utility maximizers who allocate their income across commodities based on their preferences and subject to their budget and commodity prices. To illustrate their behavior, suppose that a household consumer has a total income of $12 (and does not save or pay taxes) that it allocates to purchasing two commodities: apples, QA, with a price, PA, of $1, and oranges, QO, with a price, PO, of $2. Figure 4.2 describes the consumer's decision on how much to buy of each good. The downward-sloping, straight line, Y, in the figure is the household's

[2] This is a Cobb-Douglas utility function. See Lofgren, et al. (2002) for a discussion of alternative treatments of government and investment demand.

budget constraint. It shows all combinations of the two commodities that he can purchase for \$12. For example, points on this line include such combinations as two apples (\$2) plus five oranges (\$10) for a total of \$12; or ten apples (\$10) plus one orange (\$2) for a total of \$12.

A budget constraint drawn to the right of Y represents expenditures greater than \$12; a budget constraint drawn to its left represents expenditures of less than \$12. A utility-maximizing household that earns \$12 will always choose a basket of goods along its \$12 budget constraint. More is always better, but the household cannot afford to reach higher budget lines, and at lower budget lines, it foregoes some achievable consumption. We observe this behavioral assumption of the CGE model in the model's SAM database where, in the initial equilibrium, the income (the row total) for the household account is equal to its expenditure (the column total). This equivalence also will hold true in any post-shock model equilibrium.

If all income is spent on oranges, where Y meets the vertical axis, then quantity Y/PO, or $12/2 = 6$, oranges can be purchased. If all income is spent on apples, where Y meets the horizontal axis, then quantity Y/PA, or $12/1 = 12$, apples can be purchased. The slope of the budget constraint is calculated from the ratio of these two quantities (i.e., the rise over the run of the budget line) as $-6/12 = -1/2$. The sign is negative because the budget constraint is downward sloping; an increase in apples expenditure leads to a decrease in orange expenditure. Its slope can also be expressed as the price ratio of apples (the good on the horizontal axis) to oranges (the good on the vertical axis), since $-(Y/PO)/(Y/PA) = -PA/PO = -1/2$.

With so many feasible combinations that cost \$12, the household's choice of apple and orange quantities depends on how it ranks its preferences for goods and services – that is, its utility function. We can plot this function on a graph as an ***indifference curve***, such as U^1 in Figure 4.2. The indifference curve shows all possible combinations of apples and oranges that yield the same level of utility. Indifference curves drawn to the right of U^1 represent higher levels of utility while those drawn to its left represent lower levels of utility.

The slope of the indifference curve describes the consumer's willingness to substitute apples with oranges, or the ***marginal rate of substitution*** (MRS). Imagine, for example, that the consumer has ten oranges and only two apples at point X on the indifference curve. Based on his preferences, the consumer would be willing to forego two oranges as he moves down his indifference curve and consumes one more apple, so the MRS of oranges for one additional apple is two. As the consumer moves further down his indifference curve, and quantity of apples consumed increases, he becomes more "apple satiated." His willingness to give up oranges in exchange for an additional apple diminishes and the MRS falls. We can also express the MRS as the ratio of the ***marginal utility*** of apples (i.e., the utility derived from consuming

Text Box 4.2. A Macro-Micro CGE Model of Indonesia
"Representative Versus Real Households in the Macroeconomic Modeling of Inequality." (Bourguignon, Robilliard, and Robinson, 2003).

What is the research question? CGE models with disaggregated households contain two or more "representative" household types. These models can describe differences in the income effects of economic shocks across types of households but imply that households within each type are all affected in the same way. However, household survey data show that changes in income inequality within each household type are at least as important as cross-type changes. Could a macro-micro analysis more realistically describe the effects of shocks on the distribution of income in a country?

What is the CGE model innovation? The authors combine the IFPRI standard CGE model with a micro-simulation model based on a survey sample of 9,800 households in Indonesia. They estimate reduced-form equations that explain households' work and occupational choices as a function of exogenous parameters such as wage, age, and education. The CGE model is solved for the effects of an economic shock on endogenous variables such as wages. These CGE model results are then used as the exogenous parameters in the equations of the micro-model to analyze impacts at the household level.

What is the model experiment? The authors explore two alternative macroeconomic shocks: a 50 percent decline in the world price of Indonesia's main commodity exports and a 30 percent decline in foreign savings inflows, similar to the effect of the 1998 financial crisis. Each CGE model scenario is run under three alternative government closures: the shares of government, investment, and private consumption in aggregate spending remain the same (suggesting a successful structural adjustment program); government spending adjusts to maintain the base government budget balance; and value-added taxes adjust to maintain the base government budget balance.

What are the key findings? The macro-micro model leads to distributional effects that are different in size, and sometimes even in sign, than a CGE model with representative households. The differences reflect that the macro-micro model accounts for phenomena that are known to be important in explaining household adjustments and resulting distributional changes, including changes in types of occupation, combinations of income sources, and differences in consumption behavior within household types.

one more apple) to the marginal utility of oranges: MU_A/MU_O.[3] As more apples and fewer oranges are consumed, the marginal utility derived from

[3] The MRS is equivalent to the ratio of marginal utilities (MU_A/MU_O) because, if d refers to a marginal change, then the slope at any point on the indifference curve is $-dQO/dQA$, which is the rise over the run. The marginal utility of A is dU/dQA and of O is dU/dQO, so the ratio $MU_A/MU_O = (dU/dQA)/(dU/dQO) = dQO/dQA$, which is the negative of the slope of the indifference curve, or the MRS.

eating yet one more apple falls, and the marginal utility derived from an additional orange increases as fewer oranges are consumed. The ratio MU_A/MU_O therefore falls as the consumer moves down his indifference curve.

Consumers maximize their utility by choosing the combination of apples and oranges that provides the highest attainable utility curve given their budget constraint. In Figure 4.2, this is shown as the tangency between the budget constraint Y and indifference curve U^1, where the consumer chooses three oranges ($6) and six apples ($6) at a total cost of $12. At this tangency, the slope of the budget constraint (the ratio of prices) and the slope of the indifference curve (the ratio of marginal utilities) are equal: $MU_A/MU_O = PA/PO$. Rearranging, $MU_A/PA = MU_O/PO$. This means that the consumer maximizes utility when the marginal utility per additional dollar spent on each good is equal. If not, the consumer will spend more on the good that yields a higher marginal utility and less on the other good until their marginal utilities are equalized.

In some CGE models, household consumers are assumed to be cost minimizers instead of utility maximizers. They allocate their purchases to achieve a given level of utility with the minimum possible expenditure at given prices. Imagine that, in Figure 4.2, the consumer seeks the lowest attainable budget line with the slope $-PA/PO = -1/2$, while constrained to remain on the U^1 indifference curve. It should be evident that utility maximization and cost minimization are equivalent ways to describe consumer choice, and will yield the same ratios of demand quantities for a given level of utility.

Demand Response to Income Changes

Economic shocks in static CGE models usually lead to changes in income and in relative prices. Consumers respond by changing the quantities of goods and services that they purchase. We first consider the effect of income changes on quantities demanded. The indifference curve U^1 in Figure 4.3a describes the household's preferences for combinations of apples and oranges. The initial equilibrium is at the tangency of the budget constraint and the U^1 indifference curve, at quantities QO^1 and QA^1. An increase in income, holding relative prices fixed, shifts the budget constraint outward. It shifts outward in a parallel fashion since the price ratio of oranges and apples has not changed. An increase in income allows the consumer to increase his purchases of both goods to quantities QO^2 and QA^2, and therefore to achieve a higher level of utility, U^2. An additional increase in income shifts the budget constraint out further, enabling the consumer to increase the quantities purchased and to achieve utility of U^3. Notice that Figure 4.3a describes a utility function in which income growth causes the quantity demanded of both goods to increase by the same proportion. For example, a 10 percent increase in income,

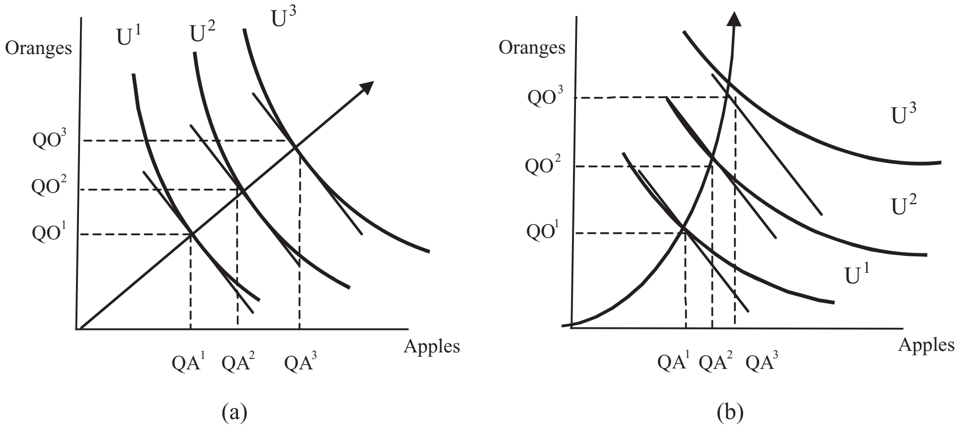

Figure 4.3. (a) Effects of income growth on consumer demand – homothetic utility function. (b) Effects of income growth on consumer demand – nonhomothetic utility function.

holding prices constant, would result in a 10 percent increase in demand for both oranges and apples. This is a ***homothetic*** utility function with income elasticities of demand of goods equal to one. As income grows, with prices constant, an expansion path plots the locus of tangencies between the budget constraint and a mapping of successively higher indifference along a straight line emanating from the origin. Many CGE models assume homothetic utility functions.

Some CGE models assume ***nonhomothetic*** utility functions, such as that drawn in Figure 4.3b. Nonhomothetic functions allow income elasticities of demand to differ from one. Some goods may be ***luxuries***, with income elasticities greater than one; others may be ***necessities*** with income elasticities of less than one. If oranges are a luxury and apples are a necessity, then income growth, with constant prices, will lead to an increase in the ratio of oranges to apples in the consumption basket. In this case, the expansion path veers toward oranges as income grows.

Demand Response to Relative Price Changes

Economic shocks in standard CGE models usually lead to larger changes in relative prices than in income, so it is worthwhile to examine carefully how demand quantities are assumed to respond to price shocks in these models. A key determinant is the ***elasticity of substitution in consumption***, denoted by parameter σ_C. The elasticity expresses the percentage change in the quantity ratio of good Y to good X given a percentage change in the price ratio of good X to good Y. Returning to our example of apples and oranges, the larger is the elasticity of substitution, the more willing is the consumer to shift to apples from oranges as the relative price of apples falls.

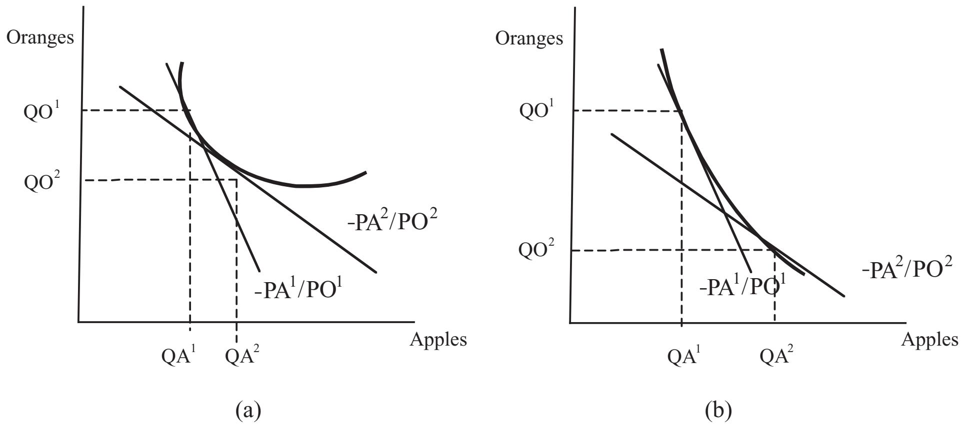

Figure 4.4. (a) Effects of price change on consumer demand, low substitution elasticity. (b) Effects of price change on consumer demand, high substitution elasticity.

Parameter σ_C describes the curvature of the indifference curve. When the parameter value is small, then the indifference curve is sharply convex, as in Figure 4.4a. In this case, an outward rotation of the budget constraint, as the price of apples falls relative to oranges, causes a relatively small change in the consumption basket, from QO^1 and QA^1 to QO^2 and QA^2. Intuitively, the more curved is the indifference curve, the faster the ratio of the marginal utility from an additional apple relative to that of an additional (MRS) falls as the ratio of apple to orange consumption rises. Therefore, the consumer is not very willing to give up oranges for an additional apple when the relative price of apples falls. When parameter σ_C is large, then the indifference curve is flatter, as in Figure 4.4b. The consumer will readily trade off oranges for an additional apple, with small effects on the fruits' relative marginal utilities. Therefore, the same decline in the relative price of apples will lead to a larger increase in the ratio of apples to oranges in the consumer's basket.

Sometimes, consumer preferences are quite rigid – for example, consumers usually buy right and left gloves in pairs. A fall in the price of right-hand gloves will not change the ratio in which gloves are purchased since most consumers require right- and left-handed gloves in a fixed proportion. Such preferences are described by a Leontief utility function, whose elasticity of substitution is zero and whose indifference curve has an L-shape. Other consumers may be completely flexible in their preferences; for example, any brand of bottled water is equally satisfactory. If a consumer is always willing to trade off the same quantity of one good for the other, then the MRS between the products is constant. Since the goods are perfect substitutes, the elasticity of substitution approaches infinity and the indifference curve is drawn as a straight line.

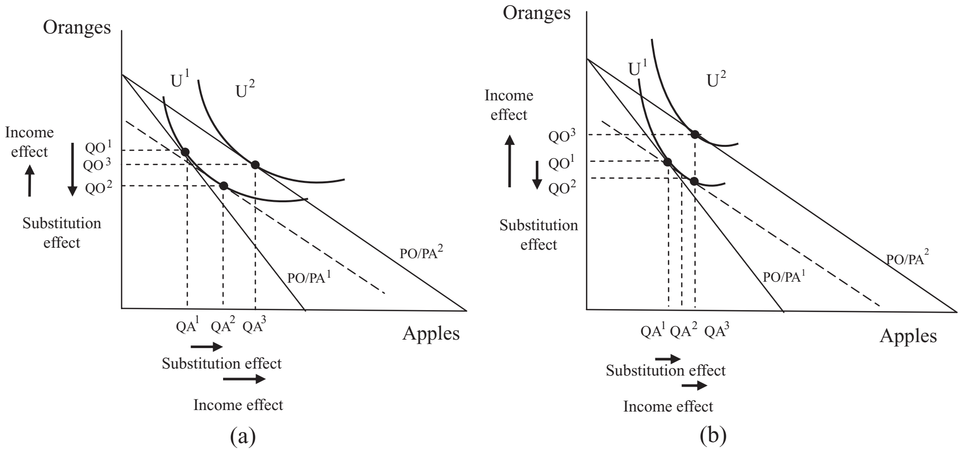

Figure 4.5. (a) Effects of price change on consumer demand – net and gross substitutes. (b) Effects of price change on consumer demand – net substitutes and gross complements.

We can decompose the effect of a price change on demand quantities into two components. First, if we assume that the own-price elasticity is negative (which is the case in standard CGE models), then the price change will cause consumers to shift the composition of their basket toward the cheaper good at any given level of utility. This is the substitution effect of a price change. It describes the movement of a consumer along the initial indifference curve as relative prices change, holding utility constant. Figure 4.5a illustrates the substitution effect of a price shock. In this example, the consumer initially purchases an orange quantity of QO^1 and an apple quantity of QA^1, at the U^1 level of utility. Suppose the price of apples falls to PO/PA^2, but the consumer is constrained to remain at the same level of utility. The dotted line, drawn parallel to the new price line, is the new price ratio. The substitution effect is the movement of the consumer along the initial indifference curve to the new basket of QO^2 and QA^2.

The second component is the effect of a price change on the consumer's purchasing power. If the price of apples falls, consumers now have money left over from purchasing their original basket. They can allocate this additional purchasing power toward buying more apples, more oranges, or more of both. The income effect of a price change measures the effect of the change in purchasing power on the consumption basket, holding relative prices constant. In Figure 4.5a, the income effect is the change from QO^2 and QA^2 to QO^3 and QA^3, at the new price ratio PO/PA^2.

By decomposing the income and substitution effects of a price change, we can describe apples and oranges as ***net substitutes*** (measuring only the substitution effect) and ***gross substitutes*** or ***gross complements*** (measuring the combined substitution and income effects). Two goods are net substitutes when a fall in the price ratio of good X to good Y cause an increase in the quantity ratio of good X to good Y, holding utility constant (i.e., remaining on the initial indifference curve). In our example in Figure 4.5a, apples and oranges are net substitutes because the fall in the relative price of apples causes the ratio of apples to oranges to increase, holding utility constant. CGE models typically assume that goods are net substitutes in consumption.

Two goods are gross substitutes if a decline in the price of one good causes demand for the second good to fall, and gross complements if demand for the second good rises. In Figure 4.5a, apples and oranges are gross substitutes. Although the income effect leads to increased demand for both fruits, the substitution effect dominates the income effect and causes the quantity of oranges demanded to fall when the price of apples declines. Figure 4.5b describes the case of gross complements. Oranges and apples are still net substitutes but now the income effect dominates the substitution effect on oranges, so the quantity of oranges demanded increases when the price of apples falls. Gross complementarity is more likely to occur when the price change affects a good that is important in the consumer's total expenditure, so that purchasing power changes substantially; when income elasticities are large, or when the substitution effect is small because the indifference curve is very convex.

Comparing Utility Functions Used in CGE Models

Our discussion of income and prices effects has emphasized how assumptions about consumer preferences, as described by utility functions and depicted in the curvature of indifference curves, determine how consumer demand responds to changes in income or in prices. CGE modelers therefore try to choose utility functions and elasticity parameter values that best describe consumer preferences in the economy that they are studying. Sometimes a modeler may need to trade off some degree of realism for feasibility when describing consumer demand. This is particularly true of modelers who want to use a standard CGE model and the utility function or demand system that it assumes, without extending the model's theory or programming. Flexibility to specify demand elasticity parameter values varies, too, since in some utility functions, these values are a "hard wired" part of the functional form or constrained in the CGE model. For these reasons, it is useful for modelers to study the functional forms commonly used to describe consumer preferences in CGE models and to understand the practical implications for their model results.

We compare four functions that are widely used in standard CGE models: the Cobb-Douglas, Stone-Geary/Linear Expenditure System (LES), Constant Elasticity of Substitution (CES) utility functions, and the Constant Difference of Elasticities (CDE) demand system (Table 4.3).

Table 4.3. *A Comparison of Functional Forms that Describe Consumer Preferences in CGE Models*

Utility Function	Elasticity: Income	Elasticity: Own-price	Elasticity: Substitution	Budget Shares: Price Change	Budget Shares: Income Change
Cobb-Douglas	Homothetic	Negative own-price	Net and gross substitutes	Fixed	Fixed
Stone-Geary/Linear Expenditure System (LES)	Quasi-homothetic	Negative own-price	Net substitutes, gross complements	Flexible	Flexible
Constant Elasticity of Substitution (CES)	Homothetic	Negative own-price	Net and gross substitutes	Flexible	Fixed
Constant Difference of Elasticities (CDE)	Non-homothetic	Negative own-price	Net substitutes, gross substitutes or complements	Flexible	Flexible

Notes: We assume that the Frisch parameter in the Stone-Geary utility function is greater than negative one, and the elasticity of substitution parameter in the CES utility function is greater than zero. See Technical Appendix 4.1 on parameter value restrictions.

The simplest (but most restrictive) is the Cobb-Douglas utility function. The function itself implies values for elasticity parameters that the modeler cannot change. For all goods, the Cobb-Douglas own-price elasticity is minus 1, and the elasticities of substitution and income are one. A unitary, negative own-price elasticity means that a change in price leads to an opposite change in quantity of an equal proportion. For example, a 10 percent increase in the apple price leads to a 10 percent reduction in apple quantity demanded. Since the quantity change in apples exactly offsets the price change, the apple budget share does not change. And, since there is no change in spending on apples, the quantities of oranges and any other goods do not change either when the apple price falls. The function therefore implies that budget shares for all goods remain fixed as relative prices change. The homothetic Cobb-Douglas utility function also implies that, if income increases 10 percent, the quantities demanded of every good also increase by 10 percent. Therefore, the budget shares of each commodity in the consumer basket remain constant when incomes alone change. Since consumers make the same substitutions in response to relative price changes at any income level, all goods are also gross substitutes.

The other three functional forms allow the CGE modeler to define one or more elasticity parameters whose values lie within specified ranges (see the Technical Appendix to this chapter). The Stone-Geary utility function differs from the Cobb-Douglas function in that it accounts for a minimum subsistence level of consumption, but above that level, preferences are described by a Cobb-Douglas utility function. For this reason, all goods are gross complements because an increase in the price of a good that meets minimum subsistence requirements means that the quantities of all discretionary goods must fall. Therefore, budget shares may vary. The Stone-Geary function is ***quasi-homothetic*** because only the demand quantities for goods that exceed subsistence levels change by the same proportion as income. Thus, budget shares of subsistence goods increase when incomes fall, and decrease when incomes rise. The smaller the share of subsistence goods in the consumption bundle, the larger is the share of the bundle that is described by a Cobb-Douglas utility function, and the more homothetic the function becomes.

The Constant Elasticity of Substitution is a homothetic utility function that allows the modeler to specify explicitly the elasticity of substitution parameter that defines the shape of the indifference curve. The name of the function, constant elasticity of substitution, derives from the fact that the substitution elasticity parameter has the same value at all points along its indifference curves and at all income levels. CGE models usually allow the modeler to define only one substitution elasticity parameter that describes identical pairwise substitutability among all goods in the consumption basket. Therefore, all goods are net substitutes (unless parameter σ_C is defined to be zero),

Text Box 4.3. Consumer Fear and Avian Flu in Ghana
"Economywide Impact of Avian Flu in Ghana: A Dynamic CGE Model Analysis." (Diao, 2009).

What is the research question? HPAI H5N1 (also known as avian flu) has attracted considerable public attention because the virus is capable of producing fatal disease in humans. Control measures have focused on its prevention and eradication in poultry populations by culling flocks, but this has not prevented a sharp fall in poultry demand by fearful consumers. Are there cost-effective and evidence-based measures that both reduce disease risk and protect the livelihoods of the small-holder farmers who account for most poultry production in Ghana?

What is the model innovation? The author develops a SAM for Ghana for 2005 that divides national production into four agro-ecological zones and ninety representative households classed by income and rural or urban location. The model is a recursive dynamic version of the IFPRI standard CGE model, which assumes the quasi-homothetic Stone-Geary utility function. Consumer aversion to chicken is simulated by reducing poultry meat's marginal budget share, a calibrated parameter in the utility function. This results in a smaller increase in poultry meat demand for any given increase in income.

What is the experiment? The production effect of avian flu is modeled as a decline in the poultry sector's capital stock (which represents the culling of chickens) that reduces production by 10 percent for periods of one to three years, an outcome that is consistent with studies of this industry. Little is known of the virus' potential effects on consumer attitudes so the demand shock is described as a change in the marginal budget share parameter that reduces poultry demand by 40 percent from the baseline time path, for periods of one to three years.

What are the results? A decline in poultry production causes a shortage in poultry supply and tends to push producer prices upward. But the decline in consumer demand tends to cause producer prices to fall. Thus, model results show little change in poultry prices due to avian flu but much lower levels of both supply and demand.

and their budget shares may change when relative prices change. Because the utility function is homothetic, consumers make the same substitutions in response to relative price changes at any income level, so all goods are also gross substitutes.

An important and useful characteristic of the Constant Difference of Elasticities demand system is that it is nonhomothetic. As incomes change, consumers can purchase proportionately more luxury goods and spend a smaller share of their budget on necessities, depending on the income elasticity of demand specified for each good. Its nonhomotheticity makes the CDE demand system especially well suited to analyze experiments in which there are large income effects. Commodities are net substitutes but the presence

Table 4.4. *U.S. Private Household Default Demand Parameters in U.S. 3x3 Database*

	Income Parameter (IINCPAR)	Substitution Parameter (SUBPAR)
Agriculture	0.25	0.74
Manufactures	0.88	0.24
Services	1.04	0.22

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

of income effects means that goods can be either gross substitutes or gross complements. For example, a fall in the relative price of a necessity good with a large budget share is likely to shift consumption toward the necessity good, but the price savings will also provide a significant boost to a household's purchasing power. This income effect will cause the quantity demanded of luxury goods to increase and that of the necessity good to fall. If this income effect is large enough, the necessity and luxury goods can be gross complements. The CDE demand system also has the flexibility to specify different pair-wise substitution possibilities in models that include more than two commodities.

We illustrate the practical significance of the choice of utility function and parameter values by comparing the model results of the same experiment when making three different assumptions about consumer preferences. Our experiment is a 10 percent increase in the productivity of factors used in the production of services. This simulates an income increase in the U.S. economy and causes the price of services to fall relative to other goods. We use the GTAP model, which has a CDE demand system because we can choose CDE parameter values that will transform the CDE function into CES and Cobb-Douglas utility functions. However, we cannot replicate the Stone-Geary utility function because it includes parameters for subsistence spending that are not accounted for in the CDE demand system.

The CDE system allows the modeler to define income and substitution parameter values. These parameters are not exactly the same as income and compensated own-price elasticities of demand, but are closely related to them.[4,5] The CDE parameter values for the United States in our 3x3 database are reported in Table 4.4. The INCPAR parameter values for the United States indicate that private household demand for services is relatively sensitive to income changes, but demand for agriculture (which is

[4] A compensated own-price elasticity describes the consumer's demand response to a price change net of the income effect; it is the movement along an indifference curve.

[5] Formulae that describe the relationship between these parameters and income, own-price and cross-price elasticities are derived by Hanoch (1975). For a detailed discussion of the CDE demand system, see McDougall (2003), Surry (1993) and Hertel, et al. (1991).

Table 4.5. *Effects of a 10 Percent Increase in Total Factor Productivity in the Services Sector on Private Household Demand Assuming Different Consumer Preferences (% Change From Base)*

	Consumer Price (*pp*)	Consumer Demand Quantity (*qp*)	Expenditure on Commodity	Budget Share
Constant Difference of Elasticities (CDE)				
Agriculture	−0.57	1.82	0.25	0.89
Manufacturing	−3.65	4.82	1.17	0.81
Services	−9.45	9.59	0.14	−0.22
Constant Elasticity of Substitution (CES)				
Agriculture	0.44	4.61	4.17	3.92
Manufacturing	−3.70	6.24	2.54	2.44
Services	−9.57	9.18	−0.39	−0.50
Cobb-Douglas				
Agriculture	−0.62	1.03	0.41	0.0
Manufacturing	−3.62	4.03	0.41	0.0
Services	−9.39	9.80	0.41	0.0

Notes: We use the Johansen solution method.
Source: GTAP v.7.0 U.S. 3x3 database.

mainly foodstuffs) is not very sensitive to income changes. As the substitution parameter value becomes larger, the negative own-price and positive cross-price compensated elasticities become larger. Based on the SUBPAR parameter values, U.S. private households are relatively price sensitive with respect to their food purchases, but less so with respect to purchases of services and manufactures.

We first carry out the model experiment using the CDE demand system. Then, we redefine income parameters and substitution parameters to correspond with a CES utility function (with a low, 0.5 elasticity of substitution) and re-run the model experiment.[6] We repeat these steps for the Cobb-Douglas utility function.

In all three model experiments, national income increases by a small amount, about 0.5 percent, which suggests that income effects on demand will be small. Other model results are reported in Table 4.5. In all three cases, the consumer price of services falls substantially relative to the prices of agricultural and manufactured goods. However, consumer responses differ in the three cases, reflecting different assumptions about consumer preferences.

[6] To describe a CES function, we define CDE utility function income parameters for all commodities and regions to be one and define all substitution parameters to be 0.5, which describes a relatively low elasticity of substitution and a highly convex indifference curve. To describe a Cobb-Douglas utility function, we define all income parameters as one, and all substitution parameters as zero. See Hertel, et al. (1991).

With the CDE function, income growth favors a disproportionate increase in quantity demanded for services, a luxury good, which reinforces the substitution toward services as their relative price falls. Nevertheless, the budget share of services falls because more services can be purchased at a lower total cost, and the budget shares of agriculture and manufactured goods increase. With the homothetic CES function, the income effect leads to a small, proportionate increase in the quantity demanded for all three commodities, which contributes to a more evenly balanced growth within the basket, compared to the CDE case. Still, as in the CDE case, the price effect causes consumers to substitute toward the consumption of services. The net effect is an increase in budget shares for agriculture and manufactured goods while the budget share of services declines. In the case of the Cobb-Douglas function, budget shares are fixed by assumption and quantities demanded for each good change by the same proportion as income. As a result, the quantities of services that consumers demand increase substantially relative to agriculture and manufacturing.

The differences in results from this simple modeling demonstration are potentially important. For example, if you were an agricultural producer, how would you assess the potential benefits to farmers of productivity gains in the U.S. services industry? Your conclusion will differ depending on the functional form and the elasticity parameter values that are assumed in the CGE analysis that you consult. Based on the CDE demand system, you may conclude that demand quantities for agricultural products will grow, but by substantially less than for other products. Based on the CES function, you may expect to participate more fully in the demand stimulus created by the service sector's productivity gains. However, based on Cobb-Douglas preferences, you may expect growth in demand for your agricultural product to be rather modest.

The right utility function for any specific analysis will depend on the research question and the flexibility offered by the CGE model to specify the utility function and the elasticity parameter values that best describe the economy under study. In general, homothetic functions are appropriate when income changes are small, as in our example, but nonhomothetic functions are better suited for shocks in which income changes are relatively large. The choice of elasticity parameter values that describe substitutability and income effects should be made with care and ideally be grounded in the empirical literature.

Import Demand

The second stage of the consumer's decision making determines the sourcing of each commodity. How much of the demand will be met by the domestically produced variety and how much will be imported? In most CGE models,

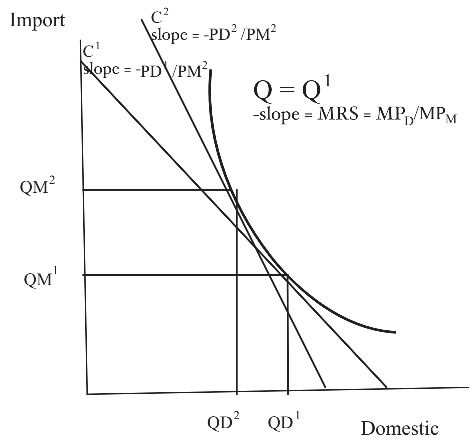

Figure 4.6. Armington aggregation function

the allocation between domestic products and imported goods reflects the assumption that the two varieties are imperfect substitutes. For example, Chilean consumers may feel that imported Chinese apples differ in flavor and texture from local apples. Chinese apples may be more suitable for baking in pies, while the Chilean variety is best eaten raw. These preferences would explain why there is two-way trade in apples between Chile and China and why the prices of the two types of apples may differ. Many CGE models describe these preferences using an ***Armington import aggregation function***. The function describes how imported and domestic apple varieties are combined to produce the composite commodity, "apples," that is demanded by Chilean consumers.

The aggregation function can be drawn as an ***isoquant***, shown as curve Q in Figure 4.6. The isoquant is similar to an indifference curve in many respects. It describes all possible quantity combinations of the imported and the domestic varieties that produce the same level of output of Q, the composite commodity. The further the isoquant lies from the origin, the larger is the quantity of Q that it represents. The negative of its slope at any point describes the MRS, which measures the quantity of imports, QM, that can be exchanged for a one-unit increase in the quantity of the domestic good, QD, holding Q constant. We can also express the MRS as the ratio of the ***marginal product*** of each variety in the production of Q, MP_D/MP_M.[7] The marginal product is the contribution to output of an additional unit of either input, holding the other input quantity constant. As the consumer moves down the isoquant, and production of Q becomes more intensive in the use of QD,

[7] The MRS is equivalent to the ratio of marginal products (MP_D/MP_M) because the slope at any point on the isoquant is $-dQM/dQD$, and since the marginal product of QD is dQ/dQD and of QM is dQ/dQM, the ratio $MP_D/MP_M = (dQ/dQD)/(dQ/dQM) = dQM/dQD$, which is the negative of the slope of the isoquant, or the MRS.

 https://doi.org/10.1017/CBO9780511975004.005

the marginal product of QD falls relative to the marginal product of QM. For example, when the consumption basket is composed mostly of Chilean apples, the addition of yet one more eating apple is not as useful to the consumer as the addition of a Chinese baking apple.

The ***Armington import substitution elasticity***, σ_M, describes the curvature of the isoquant. The smaller is σ_M, the less substitutable are QM and QD in the production of Q and the more curved is the isoquant. Each additional unit of QD relative to QM causes a relatively large decline in the ratio MP_D/MP_M. Price changes must therefore be quite large to motivate consumers to give up imports for an additional unit of the domestic variety. In the limit, when the import substitution elasticity has a value of zero, the isoquant has the L-shape of a "Leontief" function and QM will not be substituted for an additional unit of QD, regardless of any change in their relative prices. When the varieties are good substitutes, and σ_M is large, then the isoquant is relatively flat, showing that imports are easily substituted for the domestic variety, with little effect on the ratios of their marginal products in the production of Q. As the parameter value approaches infinity, the isoquant becomes linear and the two varieties become perfect substitutes.

C^1 is an ***isocost*** line with a slope of $-PD^1/PM^1$, where PD is the price of the domestic good and PM is the domestic *cif* consumer price of the imported good. The isocost line shows all combinations of the two goods that cost the same amount. Isocost lines that lie further from the origin represent higher costs. C^2 is a second isocost line, depicting price ratio PD^2/PM^2 .

The consumer minimizes the cost of producing Q by choosing the quantities of imports and domestic goods described by the tangency between the isoquant and the lowest achievable isocost line. In the initial equilibrium shown in Figure 4.6, the consumer chooses quantities QM^1 and QD^1 at a cost of C^1. At the tangency, the ratios $MP_D/MP_M = PD^1/PM^1$. Rearranging (by multiplying both sides by MP_M/PD^1), $MP_D/PD^1 = MPM/PM^1$. This means that costs are minimized when an additional dollar spent on the domestic or imported variety yields the same additional quantity of the composite good, Q. Suppose that the price of imports declines relative to the price of the domestic variety, as shown by the isocost line C^2. The least-cost ratio of input quantities shifts to QM^2/QD^2. The magnitude of the change in the quantity ratio, QM/QD, relative to the change in the price ratio, PD/PM, is determined by isoquant's curvature and the value of the import substitution elasticity parameter.

We explore the behavior of the Armington aggregation function in a CGE model by running an experiment that increases the price of imports relative to domestic goods while assuming different import substitution parameter values. We use the GTAP model and the U.S. 3x3 database to examine the effects of a five percent increase in the world import price of U.S. manufactured imports. The results, reported in Table 4.6, show that when

Table 4.6. *Effects of a 5 Percent Increase in the World Import Price of U.S. Manufactures on the Import/Domestic Quantity Ratio in Consumption (% Change From Base)*

	Armington Import Substitution Elasticity for Manufacturing		
U.S. Manufacturing	0.8	1.2	4
Import quantity (*qiw*)	−0.7	−2.6	−2.9
Domestic quantity (*qds*)	0.7	1.3	1.4
Import/domestic quantity ratio	−1.4	−3.9	−4.3

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

the goods are relatively poor substitutes, with an import substitution elasticity of 0.8, the ratio of imports to domestic goods in the consumption of manufactures falls only 1.4 percent. When goods are assumed to be readily substitutable, with a parameter value of four, the quantity response is much larger – the ratio of imports to domestic goods declines by 4.3 percent.

As you might imagine, the sizes of import substitution elasticities are an important consideration for CGE modelers who study the effects of price changes, such as tariff reforms, on production and trade. Indeed, these elasticities have received much attention in the CGE-based literature on trade policy because of the potential sensitivity of model results to the assumed parameter values. Modelers try to address these concerns by grounding their selection of parameters values in the econometric literature, and in some studies, by estimating their own elasticity parameters.[8] Modelers may also test and report the sensitivity of their results to alternative values of the parameter, as we do in this experiment.

Export Demand

Export demand is the demand by foreign consumers for the home county's exports. The treatment of foreign demand in a CGE model depends on whether the model is a multicountry model or a single-country model.

The multicountry case is straightforward: The demand for exports from country X by country Y is simply the demand for imports by country Y from country X. This is the case even when the global economy is aggregated into two regions, for example, the United States and rest-of-world, as in the model we use for demonstration. The slope of the foreign demand curve for

[8] Estimation and critiques of Armington import substitution elasticities include McDaniel and Balistreri (2003); Erkel-Rousse and Mirza (2002); Gallaway, McDaniel, and Rivera (2000); Hummels (1999); Brown (1987); and Shiells, Stern, and Deardorff (1986). See Reinert and Roland-Holst (1992); Shiells and Reinert (1993), and Hertel, et al. (2004a) for examples of studies in which CGE modelers estimated the Armington import demand elasticities used in their models.

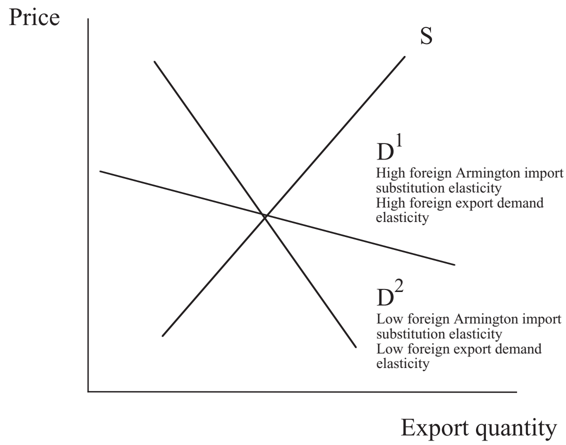

Figure 4.7. Elasticity parameters and the export demand curve

a country's export good therefore depends in part on the foreign country's Armington import substitution elasticity. The larger its value, the more elastic is its import demand and therefore the more elastic is the exporter's export demand curve.

Figure 4.7 illustrates the effect of foreign Armington elasticity parameters on a country's export demand. In the figure, S is the home country's supply of exports, D^1 describes a relatively elastic export demand curve (high foreign import substitution parameter) and D^2 describes a relatively inelastic export demand curve (low foreign import substitution parameter). For example, foreign countries' import substitution elasticities for dry milk powder are likely to be very high, because all varieties are nearly identical. The U.S.'s export demand curve for dry milk powder is therefore probably similar to demand curve D^1. In this case, even a small increase in the relative world export price of the U.S. variety can lead foreigners to make a large substitution toward their own domestic product. Conversely, a low foreign import substitution elasticity implies an inelastic export demand curve for U.S. dry milk powder.

Single-country CGE models do not describe the foreign economy or foreign import substitution preferences. Instead, the home country's export demand for each good is usually described using a simple expression:

$$QE/QW = (PXW/PE)^{\theta}$$

where QE is the country's export quantity and QW is global trade in that good, so QE/QW is the country's market share in world trade. PXW is the average global price, which is the trade-weighted sum of bilateral *fob* export prices of the good from all suppliers and PE is the *fob* world export price of the exporter's variety. Given the assumption that goods are differentiated by country of origin, a country's world export price can differ from the prices of its competitors. For example, the U.S. world export price for its corn, a yellow type used mainly for animal feed, can differ from the world export price of Mexico's corn, a white variety used mainly for food.

In the single-country model, a country can be assumed to be either ***small*** or ***large*** in its world export market by selecting the appropriate ***export demand elasticity***, denoted by θ. This parameter measures the percent change in a country's market share given a percent change in the ratio of the global price to its world export price. When a country is small, it is reasonable to assume that any change in its export quantity is too small to affect the global price level. PXW remains fixed and the export demand elasticity approaches infinity. Any change in the country's world export price relative to the global price therefore results in large changes in export quantity and market share, so its foreign demand curve is relatively flat. For example, if Uganda raises the price of its textile exports, it will not affect the world price level, but it is likely to cost Uganda a large portion of its market share in the world textile trade. Its output quantity will decline and, moving down its supply curve, its marginal costs will fall until Uganda's world export price is again equal to the prevailing global price.

When the single country is assumed to be large in world markets, then its world export price can affect the global price level and its foreign demand elasticity is assumed to be low. In this case, a change in the exporter's world price relative to the average global price causes only a small change in its market share. For example, suppose that a drought reduces Mexico's export supply of white corn and leads to an increase in its world export price. The lower the foreign demand elasticity, the less willing are foreigners to change their quantity of corn imports from Mexico as its price rises, and the steeper is Mexico's downward sloping foreign demand curve.

Consumer Welfare

"Are you better off today than you were four years ago?" This was the defining question of the 1980 presidential campaign in the United States. How you can tell that you are better off? Economists answer this question by quantifying a "money metric" measure of the change in a nation's well-being, or welfare, following an economic shock. Such a measure has a cash value, such as $14 billion, that describes the welfare change in terms of an income equivalent. In this example, we could say that a nation's consumers are now just as well off as if they had been given an additional $14 billion to spend before an economic shock. Such a measure is useful because it allows us to make unambiguous comparisons of alternative polices or other shocks. For example, we can conclude that a policy that increases national welfare by $14 billion leaves it better off than one that increases its welfare by $5 billion. CGE models are particularly well-suited to quantifying welfare effects because they describe the effects of a shock on all prices and quantities in an economy. In fact, the measurement of welfare effects is one of the most important contributions that CGE models have made in empirical economic analysis.

In this section, we describe two approaches that are commonly used to measure welfare effects in standard CGE models that have a single, representative household. We start with the most intuitive, which is the money metric equivalent of changes in "real," or the quantity of, consumption of goods and services. A quantity-based measure has intuitive appeal because it is based on the idea that larger quantities of consumption make people better off. This welfare measure includes only changes in quantities, and not the value of consumption, because value changes might be due only to price changes. For example, if I buy one candy bar both before and after a new policy changes its price from \$1 to \$2, the value of my consumption has doubled but my real consumption has remained the same – one candy bar.

We calculate the ***real consumption***, RC, welfare measure as the difference between the cost of the new basket, Q^2, and the cost of the initial basket, Q^1, valuing both baskets at the same, preshock consumer prices, P^1 for each good *i*:

$$\text{RC welfare} = \sum_{i} P_i^1 Q_i^2 - P_i^1 Q_i^1$$

Because the RC measure holds prices constant at their initial levels, a change in its value reflects only changes in quantities consumed. When the result is positive, real consumption has increased between periods one and two, and when the result is negative, real consumption has declined.

We can infer that an increase in real consumption is a welfare gain by drawing on the theory of revealed preference. At P^1 prices, the cost of Q^2 exceeded that of Q^1. Basket Q^2 was unaffordable and Q^1 was chosen. Following the shock, both Q^1 and Q^2 are affordable but Q^2 must be preferred because it is chosen. The cost difference between the baskets is equivalent to the additional income that the consumer would have needed to be able to afford the preferred basket, Q^2, at preshock prices.

All goods in the consumer basket are included in the welfare measure because a shock in one industry can affect prices and quantities throughout an economy. As an example, an import tariff reform may lower the consumer price of imported t-shirts. When the t-shirt price falls, you can either buy a larger quantity of t-shirts or, if you prefer, you can spend the money that you have saved on t-shirts to buy more of other types of goods, such as books and DVDs. Therefore, the welfare measure must account for t-shirts, books, DVDs and any other goods in your basket, even though the import tariff policy affects only t-shirts.

Table 4.7. *Calculating the Real Consumption Measure of Welfare*

	Initial Price	Initial Quantity	New Quantity	Cost of Initial Quantity at Initial Prices	Cost of New Quantity at Initial Prices
T-shirts	$1.00	10	12	$10.00	$12.00
Books	$1.00	12	16	$12.00	$16.00
DVDs	$1.00	3	8	$3.00	$8.00
Total	–	–	–	$25.00	$34.00

Table 4.7 illustrates how to calculate the real consumption welfare measure. Let's assume that we have used a three-good CGE model to analyze the effects of removing the import tariff on imported t-shirts. The original consumption basket is composed of ten t-shirts, twelve books and three DVDs. It costs a total of $25. The tariff removal causes all three consumer prices to change (these prices need not be reported). In this case, the removal of the t-shirt tariff enables the consumer to buy more of all three goods. At the original prices, the new consumption basket would have cost $34.00, or $9.00 more than the initial basket. There is a welfare gain of $9.00, which is equivalent to the additional income the consumer would have needed to purchase the new basket at the preshock prices.

Some CGE modelers take a different approach, and instead develop an ***equivalent variation***, EV, welfare measure. It, too, is a money metric measure but instead of comparing the cost of pre- and post-shock consumption quantities, it compares the cost of pre- and post-shock levels of consumer utility, both valued at base year prices. Because a CGE model contains a utility function, it is straightforward to calculate and compare the utility derived from different baskets of goods. For example, suppose the removal of the t-shirt tariff causes price changes that enable consumers to afford a new basket of goods that increases their utility from U^1 to U^2. The EV welfare effect measures the change in income that consumers would have needed to afford the new level of utility at preshock prices.[9] A positive EV welfare result indicates a welfare gain, and a negative result is a welfare loss.

To demonstrate step-by-step how to calculate an EV measure of welfare, we use a two-good example of apples, QA, and oranges, QO. Let's assume that consumer preferences in our CGE model are described by a Cobb-Douglas utility function:

$$U = QA^{\alpha} QO^{1-\alpha}$$

[9] Compensating variation is an alternative utility-based measure of welfare that compares the cost of the new versus the old utility when both are valued in post-shock prices. Similarly, the real consumption measure of welfare can be calculated by comparing the costs of two baskets when both are valued in post-shock prices.

where parameter α is the budget share for apples and, $1 - \alpha$, is the budget share for oranges. Our model will then specify the utility-maximizing demand functions for each commodity, which are derived from the utility function. In our example, the demand functions for any expenditure level, Y, and for any prices of apples, PA, and oranges, PO, are:

$$QA = \alpha(Y/PA)$$
$$QO = (1 - \alpha)(Y/PO)$$

If we assume that apples and oranges each account for a 50 percent budget share, expenditure in the base period is 100, and the initial price of apples is four and of oranges is two, then the utility function is:

$$U = QA^{.5}QO^{.5}$$

and the utility maximizing quantities of apples and oranges are:

$$QA = .5(100/4) = 12.5$$
$$QO = .5(100/2) = 25.0$$

Now we are ready to run a model experiment. Let's assume that the economic shock has caused the apple price to fall to two but that the orange price and total expenditure remain unchanged. Based on our model's demand functions, we solve for the new, utility-maximizing quantities. Using these demand functions, verify that the quantity of apples demanded increases to twenty-five whereas the quantity of oranges demanded is still twenty-five.

To calculate the equivalent variation welfare effect, our first step is to calculate the base level of utility, U^1, by substituting the base quantities for apples and oranges into the utility function:

$$U^1 = 12.5^{.5} * 25^{.5} = 17.7$$

Next, we calculate the new utility level, U^2, by substituting the new quantities into the utility function:

$$U^2 = 25^{.5} * 25^{.5} = 25.0$$

Then, we solve for the expenditure level required to achieve the new utility level at base prices by substituting the expressions for apple and orange quantities into the utility function, and solving for the total expenditure, Y. Notice that our equation incorporates the new utility level (twenty-five) and the base year prices:

$$U^2 = 25.0 = [.5 * (Y/4)]^{.5} * [.5 * (Y/2)]^{.5}$$
$$Y = \$141.6$$

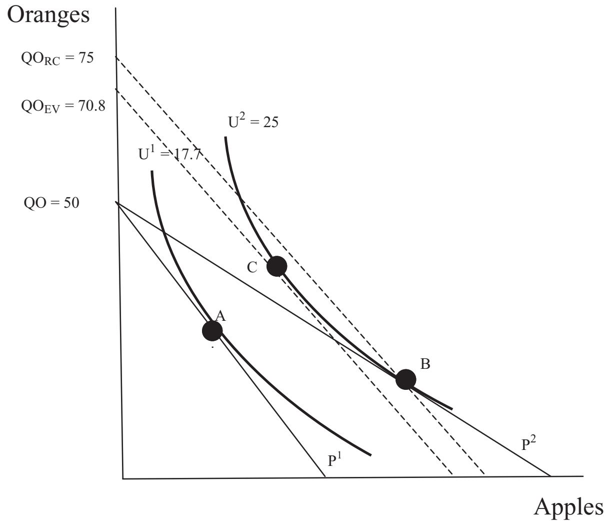

Figure 4.8. Alternative measures of consumer welfare

Last, we calculate the EV welfare measure, which is the change in expenditure that would have been required for consumers to afford the U^2 level of utility at preshock prices:

$$\$141.4 - \$100 = \$41.6.$$

For comparison, verify that the real consumption measure of welfare in this example is \$50.

The RC and the EV welfare measures are closely related. We illustrate this point in Figure 4.8, which describes and compares the results from our two-good example of apples and oranges. In the figure, the initial equilibrium is at point A on the U^1 indifference curve, given the initial price ratio between apples and oranges of P^1. The decline in the apple price is shown by the rotation of the price line to P^2. This causes the utility maximizing consumer to choose the consumption basket at point B, which provides a higher level of utility on the U^2 indifference curve. Using the real consumption measure, we can ask: "How much additional income would have been required to purchase the new basket, B, at the original prices?" The answer is shown as the vertical distance between the original budget line, and a budget line that is parallel to P^1 and goes through point B. Its intercept on the vertical axis at point QO_{RC} measures the total level of expenditure on basket B in terms of oranges, which is \$2 * 75 oranges = \$150.

Now suppose that, instead, we allowed the consumer to choose the least-cost basket of apples and oranges that generated the same U^2 level of utility as basket B, again at original prices. Given the consumer's preferences (shown by the curvature of the isoquant), that least cost bundle is at point C. Using the equivalent variation welfare measure, we can ask, "How much additional income would have been required to purchase a basket that yields the new utility level, U^2, at the original prices?" The answer is shown as the vertical distance between the original budget line, and a budget line that is parallel to P^1 and goes through point C. Its vertical intercept at point QO_{EV} describes total expenditure on basket C in terms of oranges, which is $2 * 70.8 oranges = $141.60. In this case, if original prices had actually prevailed in period two, the consumer would have substituted between apples and oranges, spending less money on a basket, C, that was as satisfying as basket B.

The welfare measure that values the change in real consumption is the distance QO-QO_{RC}. It is 25 oranges, valued at $50. It exceeds the welfare measure that values the change in utility, shown by the distance QO-QO_{EV}, which is 20.8 oranges, or $41.60.

You may verify for yourself that as the elasticity of substitution becomes smaller, and indifference curve is more sharply curved, the distance between the EV and RC intercept becomes smaller. In fact, the two approaches yield identical results when the elasticity of substitution is zero, as in a Leontief fixed-proportion utility function, with L-shaped indifference curves.

CGE models can differ in their approaches to welfare measurement in other ways, too. For example, the GTAP model measures equivalent variation welfare effects on behalf of the regional household. It therefore includes the combined changes in the utility of household consumers and government from their purchase of goods and services, and in addition includes domestic savings. Savings is included because it represents future consumption possibilities. In other CGE models, without a regional household, the welfare measure often describes only changes in quantities or utility from current consumption by private household consumers and may or may not also include investment spending. The modeler must then assume compatible macroclosure rules that fix the quantities purchased by government and perhaps of investors at their base levels.[1] It is well worth your time to study and understand the welfare measure used in your model, particularly so because this important summary measure is often presented as the "bottom line" of CGE-based analyses.

Summary

Final demand is the demand for goods and services for end use by private households, government, investors and foreign markets. Data in the row

[1] See Lofgren et al. (2002) for a discussion of the links between welfare measures and model closure.

accounts of the SAM describe the sources of income for each domestic agent and investment in the CGE model. Data in the column accounts of the SAM describe how their income is spent on commodities, and report export sales to the foreign market.

CGE models describe consumer demand as a two-stage decision. In the first stage, consumers allocate their income across commodities to maximize their utility, or satisfaction, given their preferences, budgets and prices. When income or prices change, consumers readjust their basket of commodities to again maximize their utility. We describe and compare four functional forms commonly used in CGE models to describe private households' preferences: Cobb-Douglas, Stone-Geary/LES, and CES utility functions, and the CDE demand system. Most CGE models describe the first stage of government and investment demand very simply by assuming that they spend a fixed share of their budgets on each commodity (i.e., a Cobb-Douglas utility function). In the second stage of the consumption decision, consumers minimize the cost of their consumption basket by choosing between imported and domestic products. This allocation is described by an Armington import aggregation function. In this chapter, we also describe and compare export demand in multicountry and single country models and introduce the concept of national welfare, demonstrating how to calculate real quantity and equivalent variation welfare measures.

Key Terms

Budget constraint
Budget share
Elasticity, (Armington) import substitution (σ_M)
Elasticity export demand (θ)
Elasticity, substitution in consumption (σ_C)
Equivalent variation
Final demand
Gross complements
Gross substitutes
Homothetic utility function
Import (Armington) aggregation function
Indifference curve
Isocost
Isoquant
Large country
Luxury good
Marginal product
Marginal rate of substitution

Necessity good
Net substitutes
Nonhomothetic utility function
Small country
Utility function
Welfare

PRACTICE AND REVIEW

1. Using data from the U.S. 3x3 SAM,
   a. Trace the sales of U.S.-produced agricultural goods in final demand:
      C ______________ I ______________ G ______________ E ______________
   b. Trace the sales of U.S. service-produced commodities:
      C ______________ I ______________ G ______________ E ______________
   c. In a few sentences, describe the differences in final demand for agriculture and services.
2. Using data from the U.S. 3x3 SAM,
   a. Calculate the budget shares of U.S.-produced goods in households' private consumption expenditure (including sales taxes):
      Agric: ______________ Mfg: ______________ Serv: ______________
3. Explain the difference between a homothetic and a nonhomothetic utility function. If you are conducting a study of foreign aid inflows and economic growth in a developing country, explain some of the differences in model results that you might expect to see when using the two utility functions.
4. Using a graph of the Armington aggregation function, explain the role of the Armington import substitution elasticity in determining the quantities demanded for imports and exports if the removal of a tariff causes the relative price of the import to fall. Compare the outcome in a case with a high substitution parameter value and a low parameter value.
5. Calculate the real consumption welfare effect using the data in Table 4.8. Has welfare improved or declined as a result of the price changes?

Table 4.8. *Practice and Review Calculation of the Real Consumption Welfare Measure*

	Initial Price	Initial Quantity	New Quantity	Cost of Initial Quantity at Initial Prices	Cost of New Quantity at Initial Prices
Agriculture	$1.00	5	6		
Manufacturing	$1.00	5	4		
Services	$1.00	2	8		
Total	–	–	–		

Technical Appendix 4.1: Elasticity Parameters in Utility Functions

Table 4.9 describes the elasticity parameters that are required for four functional forms commonly used in CGE models to describe private households' preferences. The table describes the restrictions usually placed on the elasticity parameter values to ensure that the CGE model can be solved for a unique solution. The table also includes a brief explanation of different parameter values.

Table 4.9. *Elasticity Parameter Values in Utility Functions Commonly Used in CGE Models*

	Modeler Input	Parameter Restrictions	Parameter Values
Cobb-Douglas	None	None	Unitary (negative) own-price; zero cross-price, and unitary substitution and income elasticities are implied by the utility function.
Stone-Geary/Linear Expenditure System (LES)	Frisch parameter (ratio of total expenditure to discretionary expenditure)	$-1 \leq$ Frisch $\leq \infty$	All expenditure is discretionary: Frisch $= -1$ All expenditure is on subsistence requirements: Frisch $= \infty$
	Expenditure elasticity by commodity (E_i).	$0 \leq E_i \leq \infty$	Luxury goods: $E_i > 1$ Necessity goods: $0 \leq E_i < 1$
	Stone-Geary/LES collapses to a Cobb-Douglas utility function when Frisch $= -1$ and all $E_i = 1$.		
Constant Elasticity of Substitution (CES)	Elasticity of substitution by commodity (σ_i)	$0 \leq \sigma_i \leq \infty$	Leontief complements: $\sigma_i = 0$ Perfect substitutes: $\sigma_i = \infty$
	CES collapses to a Cobb-Douglas utility function when all $\sigma_i = 1$; and to a Leontief utility function when all $\sigma_i = 0$.		
Constant Difference of Elasticities (CDE)	$INCPAR_i$ – a parameter related to the income elasticity of demand for good i.	$0 < INCPAR_i$	Larger $INCPAR_i$ parameter value implies larger income elasticity of demand. Income insensitive (necessity) goods: $0 < INCPAR_i < 1$ Income sensitive (luxury) goods: $1 < INCPAR_i$ Homothetic demand: $INCPAR_i = 0$ for all *i*
	$SUBPAR_i$ – a parameter related to the compensated own and cross-price elasticities of substitution, defined for good i.	Either $SUBPAR_i < 0$ or $0 < SUBPAR_i < 1$ for all *i*	Larger $SUBPAR_i$ parameter value implies larger (absolute value) of compensated own-price elasticity. Leontief complements: SUBPAR $= 1$ for all i. Goods become substitutes as $SUBPAR_i$ and $SUBPAR_j$ become smaller. Independent goods: SUBPAR $= 0$ for all i.
	CDE collapses to a Cobb-Douglas utility function when all $INCPAR_i = 1$ and $SUBPAR_i = 0$; to a Leontief utility function when $INCPAR_i = 1$ and $SUBPAR_i, = 1$; and to a CES utility function when all $INCPAR_i = 1$ and SUBPAR are identical for all i.		