6

Factors of Production in a CGE Model

In this chapter, we explore factor markets in a computable general equilibrium (CGE) model. Data in the Social Accounting Matrix (SAM) on factors of production describe factors' sources of employment and income. Important factor market concepts in the CGE model are factor mobility assumptions, the effects of factor endowment and productivity growth, complementary and substitute factors, full-employment versus unemployment model closures, and the links between factor supply and industry structure and between industry structure and factor prices.

Factors of production are the labor, capital, land, and other primary resources that producers combine with intermediate inputs to make goods and services. A nation's ***factor endowment*** is its fundamental stock of wealth because factors represent its supply of productive resources. In Chapter 5, we considered production activities' demand for factors and how these adjust with changes in relative factor prices or output levels. Many other dimensions of factor markets in a CGE model also deserve study.

In the next sections, we describe factor markets in CGE models in detail, focusing on those aspects that are of greatest practical importance for CGE modelers. We begin by studying the factor market data in the SAM. Then we consider the behavior of factor markets in the CGE model. We explain factor mobility assumptions, which govern the readiness of factors to change their employment in response to changing wages and rents across industries. We explore the effects of changes in the supply, or endowment, of factors, and contrast it with changes in the "effective" endowment when factor productivity changes. We study the implications of assuming production functions, or industry technologies, that treat factors as complements (low factor substitutability) versus substitutes (high factor substitutability). We describe the CGE model's closures rules that specify full employment versus factor unemployment and demonstrate the importance of this assumption for model results. Finally, we examine the links between factor markets and the industry structure of an economy. We study how a change in factor

Table 6.1. *Factors of Production Data in the SAM ($U.S. billions)*

	Production Activities			Factors		
	Agriculture	Manufacturing	Services	Land	Labor	Capital
Land	34	0	0			
Labor	68	1,109	5,667			
Capital	122	467	2,332			
Income tax	0	0		3	1,446	244
Regional household	0	0		31	5,397	1,632
Savings–investment	0	0	0	0	0	1,046
Total	na	na	na	34	6,844	2,921

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

endowments leads to changes in the industry structure, and we examine how changes in industry structure leads to changes in factor prices and factor input ratios across industries.

Factors of Production Data in a SAM

Each factor of production has its own row and column account in a SAM. For example, in the U.S. 3x3 SAM, there are three factors of production: land, labor, and capital (Table 6.1). The factor row accounts describe the receipt of income earned from employment in agriculture, manufacturing, and services activities. For example, land receives $34 billion from employment in agricultural production. Labor receives income from all three production activities: $68 billion from employment in agriculture, $1,109 billion from employment in manufacturing, and $5,667 billion from employment in services. Capital also receives income from all three production activities.

The SAM's factor column accounts report the disposition of factor income. First, there are income taxes based on factor earnings. Land rental income incurs $3 billion in taxes. In this database, the $1,446 billion in labor income tax includes payroll taxes such as Social Security. The SAM, and the CGE model that we use for most of our examples in this book, assume that their after-tax factor earnings are paid to a regional household, a macroeconomic account. Capital pays $244 billion in income taxes. In addition, the capital account column reports depreciation as a cost that is allocated to the investment-savings account. Capital's remaining income is paid to the regional household account.

CGE models generally have at least two factors of production. Often, researchers disaggregate factors into many more types. For example, they may disaggregate labor into skilled and unskilled workers or urban and rural

workers. Modelers also may disaggregate the capital account to separate capital equipment and structures from natural capital resources such as coal and oil. Sometimes, CGE modelers disaggregate land into types, such as cropland versus grazing land, or irrigated and nonirrigated land. You can visualize factor market disaggregation in a SAM by imagining that instead of a single labor row and labor column account, there are, for example, two labor rows and two labor columns – one each for skilled and unskilled labor. By disaggregating factors, the researcher who is interested in factor markets can pursue a richer analysis of some types of economic shocks. For example, a labor economist may be interested in differentiating the effects of immigration on skilled versus unskilled wages.

Factor Mobility

Factor mobility describes the ease with which labor, capital, and other factors can move to employment in different production activities *within a country* as wages and rents change across industries. Some multicountry CGE models also allow factor mobility *across* countries, which changes nations' factor supplies. A CGE model of this type supported a recent World Bank analysis of global labor immigration, summarized in Text Box 6.1. In this chapter, we assume a nation's factors are in fixed supply, except when we explicitly consider, as in the next section, the ramifications of a change in factor endowments.

In a CGE model, factors are called ***fully mobile*** if they are assumed to move among jobs until wage and rent differentials disappear. For example, if workers perceive that one industry offers a higher wage than another, some number of them will exit the low-wage industry, causing its wage to rise, and enter the high-wage industry, causing its wage to fall. Their movement will continue until wages in the two industries are equal. Full factor mobility is probably a realistic view of labor and capital markets in the medium run or long run because transition costs, such as retraining and job search costs, become less important when they are amortized over a longer time horizon. Younger workers, for example, may decide it is worth the time and money to invest in training for higher-paying jobs in industries that seem to offer a bright future over the remaining span of their careers.

Some CGE models allow factors to be ***partially mobile***. This assumption implies that transition costs are large enough to discourage some workers or equipment from changing employment unless pay differences are sufficient to compensate them for the cost of moving to other employment. Wages and rents can therefore diverge across production activities and, given identical shocks, factor movements are usually smaller with partially mobile factors than in a CGE model that assumes full factor mobility.

Text Box 6.1. The Economic Impacts of Global Labor Migration
***Global Economic Prospects 2006*,** World Bank, Washington D.C.

What is the research question? The United Nations estimates that international migrants account for about 3 percent of the world's population. International labor migration can generate substantial welfare gains for migrants, their countries of origin and the countries to which they migrate but may also lead to social and political stresses. What is the estimated size of the economic welfare effect of global labor migration?

What is the CGE model innovation? The authors modify the World Bank's recursive dynamic CGE model, Linkage (van der Mensbrugge, 2005), to work with their comprehensive global database on labor migration, which differentiates between migrant and native workers and tracks remittance income sent by migrants to their countries of origin. They also adapt their welfare measure to account for the effects of cross-country differences in the cost of living on the spending power of migrant wages and remittances.

What is the model experiment? Migration flows from developing to high-income countries are assumed to increase at a rate sufficient to increase the labor force of high-income countries by 3 percent over the period 2001–25. The assumed increase, roughly one-eighth of a percentage point per year, is close to that observed over the 1970–2000 time period.

What are the key findings? Migration yields large increases in welfare for both high- and low-income countries. Migrants, natives, and households in countries of origin all experience gains in income, although income falls for migrants already living in host countries. There is a small decline in average wages in destination countries but migration's effect on the long-run growth in wages is almost imperceptible. Both the costs and the benefits of migration depend, in part, on the investment climate.

CGE models that allow partial factor mobility use a factor supply function for each partially mobile factor. This concave function is identical to the export transformation function described in Chapter 5, so we do not replicate it here. Using labor as an example, the function describes how the labor force can be transformed into different types of workers, such as agricultural or manufacturing workers. A ***factor mobility elasticity***, σ_F, defines the percentage change in the share of the labor force employed in sector X given a percentage change in the ratio of the economy-wide average wage to its industry wage. For example, if the wage in sector X rises relative to the average wage, then the share of the work force employed in sector X will rise. The factor mobility parameter value ranges between close to zero, which is an immobile factor, to minus 1, which is a fully mobile factor. The higher is this elasticity (in absolute value), the larger are the employment shifts in response to changes in wages and rents across industries. CGE

Table 6.2. *Capital Rents (pfe) by Sector with a 5 Percent Subsidy on Private Household Consumption of Domestic Manufactures, Under Alternative Capital Mobility Assumptions*

	Agriculture	Manufacturing	Services
Fully mobile capital	1.1	1.1	1.1
Partially mobile capital	1.4	3.9	0.2
Sector-specific capital	3.4	4.4	0.0

Note: Fully mobile capital has a factor mobility elasticity (etrae) of minus 1, partially mobile capital has an elasticity of minus .2 and sector-specific capital has an elasticity of minus .0001.
Source: GTAP model, GTAP v.7.0 US 3x3 database.

models that describe factor mobility in this way may assume a Constant Elasticity of Transformation (CET) factor supply function, so that parameter σ_F is the same for all ratios of factor employment and at all levels of aggregate factor supply.[1]

In the short run, some factors may be immobile, also called ***sector-specific***. That is, factors do not move from the production activity in which they originally are employed, regardless of the size of changes in relative wages or rents across industries. This assumption is often made in the case of capital because existing equipment and machinery are typically hard to transform for use in different industries. Similar to the case of partially mobile factors, the wage or rent of the sector-specific factor can differ across industries in the model – perhaps significantly so, because no amount of wage or rent premium can be enough to attract factors that are stuck in their current employment, or low enough to motivate them to quit.

A practical implication of the factor mobility assumption is that it influences the slope of industry supply curves. All else equal, the more mobile are factors, the flatter is the supply curve and the larger is the supply response to any type of economic shock. One way to think about it is that a producer who can easily attract more factors with a small wage or rent increase is better able to increase output while holding down production costs, so his supply curve is more elastic.

We explore the effects of alternative factor market assumptions in a CGE model by using the GTAP model and the U.S. 3x3 database to run an experiment that introduces a 5 percent subsidy to private households in the United States on their purchases of domestically produced manufactured goods. The subsidy stimulates demand for manufactures, so producers try to increase their output by hiring more labor and capital. The results reported in Table 6.2 describe the subsidy's effects on each industry's capital rents in

[1] See the section on export supply in Chapter 5 for a more detailed discussion of CET functions.

models with three different capital mobility assumptions – fully mobile, partially mobile, and sector-specific. When capital is fully mobile, it moves across industries until capital rents equalize, so the capital rents increase by the same rate in every industry. In this case, manufacturing output increases 3.7 percent. When capital is only partially mobile, intersectoral differences in rental rate emerge. Manufacturing's capital rents are higher and its output expands by slightly less, 3.5 percent. The capital rent in U.S. manufacturing rises most when capital is assumed to be sector-specific, and manufacturing output increases least in this model, by 3.4 percent.

Factor mobility assumptions are a useful way to categorize CGE model results as describing ***short-run***, ***medium-run***, or ***long-run*** adjustments to economic shocks. In the short run, some factors – usually capital – are immobile, and the economy's production response is therefore limited. In the medium run, factors are partially, or even fully, mobile. In this case, the adjustment period is long enough that existing stocks of capital and labor can be retooled or replaced, and workers can shift employment among industries in response to changes in wages and rents. Production therefore becomes more responsive to economic shocks. Analyses of long-run adjustment assume that all factors are fully mobile and, in addition, long-run changes in factor supply and productivity occur. The standard, static CGE models that we are studying can describe short- and medium-run adjustments, depending on their factor mobility assumptions. Dynamic CGE models that are capable of describing factor accumulation and productivity growth are needed to describe long-run adjustments to economic shocks.

Factor Endowment Change

A standard assumption in static CGE models is that a nation's factor endowments are in fixed supply. CGE modelers analyze shocks to factor endowments as model experiments. These shocks can occur for many reasons, such as immigration (increases the labor supply), foreign direct investment (increases the capital supply), or war (decreases both labor and capital supplies). A change in factor endowments can be a significant shock because it changes the productive capacity of an economy. Often more important from a public policy perspective, are the resulting distributional effects when a change in a factor endowment leads to increased wages or rents earned by some factors, but lower earnings by others.

An increase in the supply of a factor will cause its wage or rent to fall (unless demand for the factor is perfectly elastic). As an example, Figure 6.1 illustrates the effect of an increase in the supply of labor, from S_L^1 to S_L^2, on employment and wages. The national labor supply curve is a vertical line because we assume, as in a standard CGE model, that there is a fixed supply

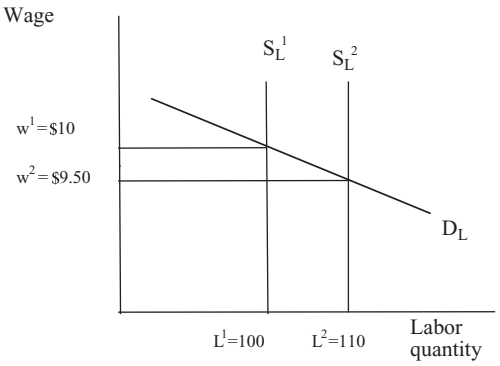


Figure 6.1. Effect of an increase in labor endowment on employment and wages

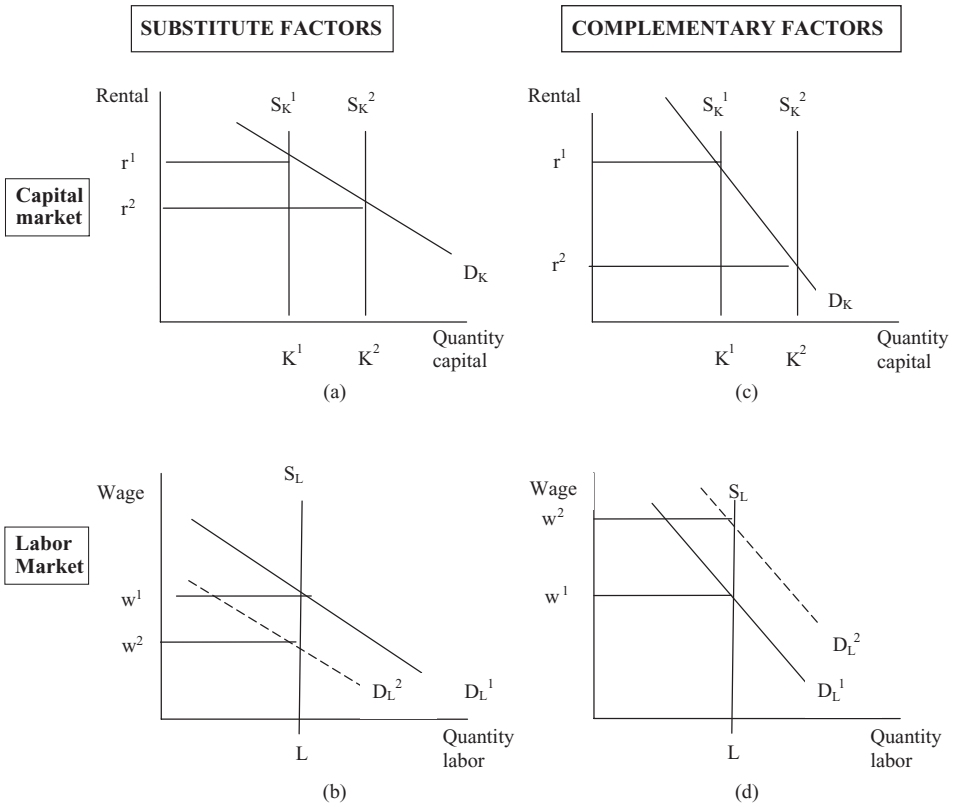
of workers and all of them are employed. D_L is the labor demand curve. In our example, there are initially 100 workers earning an equilibrium wage, w^1, of $10 per worker. An increase in the labor supply to 110 workers causes the market-clearing wage to fall to $9.50.

We observe the effects on aggregate output and the own-price of a factor endowment change in a CGE model by using the GTAP CGE model and the U.S. 3x3 database to run an experiment that increases the U.S. labor supply by 10 percent. The result is a 2 percent decline in the U.S. wage and a 7 percent increase in U.S. real GDP.

Factors as Complements and Substitutes

A change in the endowment of one factor can also affect the demand for and prices of other factors of production. For example, an increase in the supply of labor – perhaps due to immigration – will affect the wage in the host country, and the demand for and price of capital that is used in combination with labor to produce goods and services. However, we cannot say for sure how immigration will affect capital. Whether the quantity of capital demanded and capital rents will rise or fall depends on whether labor and capital are substitutes or complements in the production process.

We have already studied factor substitutability and complementarity in our description of producers' demand for value-added in Chapter 5. To reiterate briefly, the firm's technology determines the ability of producers to substitute labor for capital in the production of a given level of output. We depicted the flexibility of technology with a ***factor substitution elasticity***, σ_F, which defines the percentage change in the ratio of capital to labor given a percentage change in the ratio of wages to rents. If the parameter has a large value, the two factors are close ***substitutes***. The increase in the labor supply is more likely to cause rents to fall because firms will shift toward labor, the cheaper



Figures 6.2a–d. Labor and capital as substitutes and complements

factor, and demand less capital for use in their production processes. If the elasticity has a small value, then the two factors are close ***complements***. In this case, the increase in the labor supply is likely to increase capital rents as firms hire demand more capital equipment to use with their new workers.

As another example, consider the case of a country that receives foreign aid in the form of capital equipment and machinery. Will this increase in its capital stock raise or lower its wages – will it help or harm its labor force? Figure 6.2 presents a four-quadrant graph that illustrates the effects of the increased supply of capital goods on the country's capital and labor markets under the alternative assumptions that capital and labor are substitutes or complements. Figures 6.2a and 6.2b describe the markets for capital and labor when the two factors are highly substitutable. Figures 6.2c and 6.2d describe the markets for capital and labor when the two factors are more complementary. Notice that the factor supply curves for both factors are shown as vertical lines, reflecting our CGE model assumptions of fixed factor endowments and full employment. In both capital market figures, an increase

in the capital stock shifts the supply curve for capital to the right, from S_K^1 to S_K^2. In the two labor market figures, the increase in capital stock shifts the demand curve for labor in opposite directions, from D_L^1 to D_L^1.

First, we assume that capital and labor are strong substitutes. Perhaps in this country, industries can easily produce goods using either machinery or workers, so the demand for capital, D_K, is elastic (and drawn with a relatively flat slope) and the initial capital rent is r^1. An increase in the capital stock, from S_K^1 to S_K^2, in Figure 6.2a, causes the price of capital to fall so producers substitute toward more cost-saving, capital-intensive production processes. In the new equilibrium, the quantity of capital demanded has increased from Q_K^1 to Q_K^2 and the capital rent has fallen to r^2.

The effect of the increase in capital on the labor market is shown in Figure 6.2b by the direction of the shift in the demand curve for labor. A shift to more capital-intensive processes is shown as a decline in the economy's demand for labor, from D_L^1 to D_L^2. As the adoption of more capital-intensive production technologies reduces the demand for the fixed supply of workers, the wage falls from w^1 to w^2.

Contrast this outcome with the case of factors as strong complements. For example, perhaps capital equipment requires workers to operate it. The demand curve for capital equipment is thus relatively inelastic, with the steep slope shown by D_K in Figure 6.2c. The effect of capital stock growth on the demand for complementary labor is shown in Figure 6.2d as a rightward shift in the labor demand curve, from D_L^1 to D_L^2. In this case, the demand for labor increases, causing the wage to rise from w^1 to w^2.

We study the role of the factor substitution elasticity in a CGE model by using the GTAP model to carry out an experiment that increases the U.S. capital stock by 10 percent. We compare the factor price results from two versions of the model. We first define capital and labor as strong substitutes and then as strong complements by changing the factor substitution elasticity parameters for all three production activities in the model.

Model results, reported in Table 6.3, show the key role of the factor substitutability assumption in determining whether a change in the supply of one factor raises or lowers the price of the other factor. When factors are strong substitutes, an increase in the U.S. capital stock lowers U.S. wages by .45 percent. If factors are assumed to be strong complements, an increase in the capital stock raises wages by 1.84 percent. In both cases, an increase in the capital stock lowers the price of capital.

Factor Productivity Change

Factor productivity describes the level of output per unit of factor input. An increase in factor productivity means that the same quantity of a factor can

Table 6.3. *Effects of 10 Percent Capital Stock Growth on Wages and Rents in the U.S. 3x3 Model When Factors are Substitutes or Complements (% change from base)*

% Change	Substitutes	Complements
Wage (pfe_L)	−.45	1.84
Rent (pfe_K)	−.52	−5.29

Note: Substitutes case specifies factor substitution elasticities for all production activities of 125. Complements case uses default GTAP elasticities. The model closure fixes the U.S. trade balance, DTBALr.
Source: GTAP model and GTAP v.7.0 U.S. 3x3 database.

produce more goods and services. New training, for example, may enable an autoworker to produce twice as many vehicles as previously whereas bad weather may cause an acre of land to yield only half the usual quantity of wheat. Productivity gains and losses can occur for a single factor (such as the labor productivity losses described in Text Box 6.2) or for a subset of factors, and in one or more industries. A change of equal proportions in the productivity of all factors of production in an industry or in an economy is called a change in ***total factor productivity*** (TFP).

A change in a factor's productivity changes the ***effective factor endowment***. Effective factor endowments take into account both the quantity and the efficiency of a factor. For example, suppose that an initial labor supply of 100 workers can now do the work of 110 workers (a 10 percent gain in their productivity), then the effective labor endowment is now 110 workers, although the actual number of workers remains at 100.

An increase in productivity tends to lower the wage per effective worker. This point is illustrated in Figure 6.3. Note carefully that its axes and curves refer to the quantity of and wage per effective worker, not actual workers, where EL is the quantity of effective workers. The demand curve for effective labor is D_L and $S_L{}^1$ describes its supply. In the initial equilibrium, the economy employs 100 workers at a wage of $10. An increase in labor productivity shifts the supply of effective workers to $S_L{}^2$. Given the labor demand curve, the new equilibrium has 110 effective workers at a wage per effective worker (the ***effective wage***) of $9.50. It may seem surprising that a factor's productivity gain could lead to a lower wage or rent, but remember that this is the price of an effective factor. Because 110 effective workers equal 100 actual workers, the wage per actual worker has *increased* to $10.45.[2]

[2] The actual wage is derived by calculating the total wage bill as the product of effective workers times the effective wage (110 * $9.50 = $1,045) and dividing it by the number of actual workers ($1,045/100 = $10.45).

Text Box 6.2. HIV/AIDS – Disease and Labor Productivity in Mozambique
"HIV/AIDS and Macroeconomic Prospects for Mozambique: An Initial Assessment." (Arndt, 2002).

What is the research question? As in other countries in the southern Africa region, a human development catastrophe is unfolding in Mozambique, where HIV prevalence rates among the adult population in 2000 are around 12 percent, and life expectancy is projected to decline to about 36 years. Due to the magnitude of the HIV/AIDS pandemic, it has overrun the bounds of a pure health issue and become a top priority development issue. What is the scope of its potential macroeconomic impact?

What is the CGE model innovation? The author develops a recursive dynamic CGE model, based on the IFPRI standard CGE model that updates sectoral productivity, the labor force (by skill category), and the physical capital stock to analyze the effects of HIV/AIDS over time.

What is the model experiment? There are three channels through which the HIV/AIDS pandemic is assumed to affect economic growth: (1) productivity growth effects for labor and other factors, (2) population, labor, and human capital stock accumulation effects, and (3) physical capital accumulation effects. Based on these channels, the author defines four scenarios. An AIDS scenario reduces all factors' productivity and endowments based on available estimates; a "less-effect" scenario reduces most of the HIV/AIDS impacts by about one-half. An education scenario combines the AIDS scenario with a strong effort to maintain school enrollments and the growth of the skilled labor supply. A No-Mega scenario combines the AIDS scenario with the assumption that large scale, donor-financed investment projects are curtailed.

What are the key findings? The differences in growth rates in the four scenarios cumulate into large differences in GDP over time. GDP is between 16 and 23 percent smaller than it would be in the absence of the pandemic. The major impacts on GDP are decomposed into the three channels. Although all are important, the decline in factor productivity is the largest source of the potential decline in Mozambique's GDP.

Similar to an endowment change, when the effective endowment of one factor changes, it may affect the demand for and prices of other factors. In Chapter 5, we showed how a change in one input price could lead to substitution and output effects on the demand for both factors. In the case of a change in the effective price, we decompose three effects. The first two are the same substitution and output effects that we have already studied. For example, if labor productivity increases, a fall in the effective wage motivates producers to become more labor-intensive and use less capital for any given output level, to the extent that their technology allows it. Automakers, for

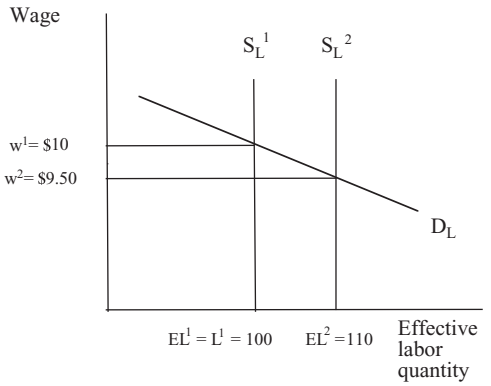


Figure 6.3. Effect of an increase in labor productivity on employment and wages.

instance, will want to use more of the newly trained autoworkers and less equipment to produce their current output quantity because the cost of labor per auto has fallen relative to the cost of capital. This is the substitution effect of productivity changes on the demand for actual workers and for capital. Second, given the competitive markets assumed in standard CGE models, a fall in production costs due to increased productivity is passed on to consumers through lower product prices, which in turn leads to higher demand and production levels. The output effect describes an increase in demand for all factors by the same proportion as the change in output, holding relative factor prices constant. The third, additional, effect is the impact of a factor's productivity change on demand for that factor, for a given output level. Automakers, for example, will need fewer workers to produce the same number of cars when labor productivity increases. The net effect of a factor's productivity change on demand for all factors in the economy is the sum of the substitution, output and productivity effects.

We illustrate these three effects in a CGE model using the GTAP model with the U.S. 3x3 SAM. Our experiment assumes a 10 percent increase in the productivity of the total U.S. labor force; for brevity, we report results only for the capital and labor markets. The factor substitution effect leads to a substitution toward labor and away from capital in all three industries as the effective wage falls (Table 6.4). The output effect in each industry is identical for both factors and is the same as their percent growth in output. The 10 percent increase in labor productivity also leads to a reduction of an equal proportion in firms' demand for workers. Notice that there is no productivity effect on capital demand because its productivity is unchanged in this experiment. On net, the resulting changes in factor demand cause the effective wage to fall by 4.2 percent, the actual wage to rise by 5.8 percent, and capital rents to increase by 3.3 percent.

Table 6.4. *Effects of a 10 Percent Increase in Economywide U.S. Labor Productivity on Demand for Labor and Capital (% change from base)*

	Agriculture	Manufactures	Services
Labor demand (*qfe*)	−7.4	−1.7	0.4
Factor substitution effect (*qfe-qo-afe*)	1.2	2.6	2.8
Output effect (*qo*)	1.4	5.7	7.7
Productivity effect (*afe*)	−10.0	−10.0	−10.0
Capital demand (*qfe*)	1.0	−1.0	0.2
Factor substitution effect (*qfe-qo-afe*)	−0.4	−6.7	−7.5
Output effect (*qo*)	1.4	5.7	7.7
Productivity effect (*afe*)	0.0	0.0	0.00

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

Factor Unemployment

In some countries, unemployment is a serious problem, and the common CGE model assumption of full employment of all factors may not realistically describe an economy. Unemployment can be depicted in a CGE model by changing the factor market closure. Recall from our discussion in Chapter 2 that model closure is the modeler's decision as to which variables adjust to re-equilibrate markets following an economic shock. With a full employment model closure, a shock to an economy causes wages and rents to adjust until the fixed supply of each factor is again fully employed. In a model with an ***unemployment*** closure, the wage or rent is assumed to be fixed, and economic shocks can lead to a change in the factor supply – that is, the size of the labor force or the stock of capital will adjust until factor supply and demand are again equal at the initial wage or rental rate.

In a model that allows unemployment, a decline in the size of the labor force, for example, means that some proportion of workers is now unemployed, so part of the nation's productive capacity is now idled. An increase in the size of the labor force means that previously unemployed workers have now found employment, so the economy's productivity capacity expands. In this case, industries are able to hire as many workers or as much equipment as they need following an economic shock, without bidding up wages or capital rents. As you might expect, experiments in a model that allows factor unemployment can result in very large changes in a nation's productive capacity and real GDP.

We explore the implications of the factor market closure assumption in a CGE model by comparing the effects of the same experiment in model versions with different labor market closures. We use the GTAP model and the U.S. 3x3 database to run an experiment that provides a 10 percent output

Table 6.5. *Effects of a 10 Percent Output Subsidy in U.S. Manufacturing Under Full Employment and Unemployment Labor Market Closures (% change from base)*

	Labor Unemployment Closure	Full Employment Closure
Manufacturing employment (*qfe*)	15.1	5.2
Manufacturing output (*qo*)	44.3	5.3
Wage (*pfe*)	0.0	13.4
Labor Supply (*qo*)	60.1	0.0
Real GDP (*qgdp*)	41.4	0.1

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

subsidy in U.S. manufacturing. Model results show that the alternative factor market closures depict very different adjustments by the U.S. economy to the same economic shock (Table 6.5). Notably, when we assume an unemployment closure, there is a large expansion of manufacturing employment and output because the total U.S. labor supply increases by 60.1 percent. However, if labor is assumed to be fully employed, then manufacturers must compete for workers with other industries in order to expand production. This competition drives up wages and increases manufacturers' cost of production – costs that must be passed on to consumers through higher prices. Manufacturing production therefore does not grow as much in the full employment scenario compared to the unemployment scenario. In addition, real GDP growth is far larger (41 percent) if previously unemployed workers can be added to the nation's stock of productive resources, compared to only .1 percent growth in real GDP when factors are already fully employed.

Factors and Structural Change

The industry structure of an economy describes the share of each industry in total national output. For example, from Table 3.3, the structure table for the United States, we know that agriculture accounts for 2 percent of U.S. GDP and services accounts for 81 percent of GDP. Industry structure is linked to factor markets in two ways. First, all else equal, an increase (decrease) in the endowment of a factor causes an increase (decrease) in the relative size of industries that are most intensive in the use of that factor. Second, a change in industry structure affects relative factor prices and factor intensities. The relative price of the factor used most intensively in expanding industries rises, and the relative price of the factor used most intensively in declining industries falls, motivating both types of firms to substitute toward the cheaper factor.

Table 6.6. *Effects of 10 Percent Increase in the Capital Endowment on the Structure of U.S. Production*

	Capital Share in Total Factor Cost	Percent Change in Output
Agriculture	54	5.7
Manufacturing	27	5.4
Services	27	2.1

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

Let's consider the first linkage in more detail. An industry is intensive in the use of the factor that accounts for the largest share of its total factor costs. Because the increase in the supply of a factor usually lowers its price, the cost savings will be greatest for those firms that use the factor most intensively. For example, a lower capital rental rate in the U.S. economy would most benefit U.S. agriculture – the most capital-intensive sector in the United States. In the competitive economy that we assume in our CGE model, farmers can therefore lower their sales price by proportionately more than other firms can. These price changes will tend to cause demand for and production of food to increase relative to other goods, depending on consumer preferences.

We can observe this linkage in a CGE model by using the GTAP model and the U.S. 3x3 database to carry out an experiment that increases the U.S. capital supply by 10 percent. This causes the capital rental rate in the United States to decline by almost 7 percent. The greatest cost savings occur in U.S. agriculture, in which capital costs account for more than half of its total factor payments. Lower capital rents cause output to increase in all three sectors but it increases by proportionately more in agriculture than in other industries (Table 6.6).

Next, we consider the link between ***structural change*** and factor returns. The structure of a nation's output can change for many reasons. For example, over time, services have become a larger part of the U.S. economy and the role of manufacturing has diminished. Trade shocks, such as a foreign embargo on a home country's exports, or a boom in export demand, can also cause structural change in an economy's output. Government programs, such as subsidies and taxes targeted at specific industries, can cause structural change, too. Factor prices change when industries that are expanding and contracting have different factor intensities in their production technologies.

To understand why, consider a simple, two-industry country, in which the capital-intensive sector (agriculture) is expanding. The agricultural production process uses one worker and three units of capital per unit of output. The other industry (services) is labor-intensive; it uses three workers and

Table 6.7. *Effects of a 10 Percent Production Subsidy to U.S. Manufacturing and Agriculture on Factor Prices and Factor Intensities (% change from base)*

	10% Production Subsidy to:	
	Manufacturing	Agriculture
Wage (pfe_L)	13.44	0.18
Capital rent (pfe_K)	13.05	0.23
Capital/labor input ratio ($qfe_K - qfe_L$)		
Agriculture	0.06	−0.01
Manufacturing	0.45	−0.07
Services	0.47	−0.08

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

only one unit of capital for every unit of output. If agricultural production expands by one unit, it needs to hire three new units of capital and one new worker. However, when three units of capital leave the services industry, nine workers also become available for hire. There is now an excess supply of labor in the economy, which will cause wages to fall relative to rents. As labor become cheaper than capital, the agricultural industry has an incentive to become more labor intensive by using more workers per machine (assuming its production technology allows some factor substitution). As the services industry's capital is bid away by agriculture, and with wages falling, service producers have the same incentive to become more labor intensive (assuming their technology allows it). In the new equilibrium, if all workers and capital are re-employed (the full employment assumption), then wages will have fallen relative to rents, and both industries will have become more labor intensive than they were initially.

We can observe the effects of structural change on factor returns and factor intensities in a CGE model by comparing results from two separate experiments that change the structure of U.S. production in different ways. We use the GTAP model with the U.S. 3x3 database to introduce (1) a 10 percent production subsidy to U.S. manufacturing, a labor-intensive activity, and (2) a 10 percent production subsidy to U.S. agriculture, a capital-intensive activity. For brevity, we discuss only labor and capital markets and omit discussion of the land factor.

Results, reported in Table 6.7, describe the effects of the two experiments on wages and capital rents, and on the factor intensity of production activities. Structural change that favors the labor-intensive, manufacturing industry causes the wage to rise slightly relative to capital rents, and all three production activities to become more capital intensive. Structural change that favors the capital-intensive, agriculture industry causes capital rents to rise relative to wages and all three production activities to become more labor intensive.

The impacts are far smaller in magnitude in the case of agriculture because it accounts for only a small share of U.S. economic activity.

Summary

This chapter examined several important aspects of factor market behavior in a CGE model. We first described the factor market data in the SAM, which reports the sources of factor income and factor expenditure on taxes, depreciation and the regional household account. In the CGE model, factor mobility assumptions govern the readiness of factors to change their employment in response to changing wages and rents across sectors. An economy's supply response is larger when factors are more mobile. Factor endowments are usually assumed to be in fixed supply in standard CGE models, and modelers may change factor endowments as an experiment. We learned that an increase (decrease) in the supply of a factor usually causes its price to fall (rise), but that the effect on demand for and prices of other factors depends on whether the factors are substitutes or complements in the production process. Full employment of all factors is a common assumption in CGE models, but this may not be a realistic depiction of labor markets in many countries. We described the alternative model closures of full employment and unemployment and show how they depict different adjustments by an economy to economic shocks. Finally, we examined the links between economic structure and factor markets. When a change in factor endowments causes relative factor prices to change, it changes the costs of production for industries, and leads to an expansion (contraction) in the output of industries whose costs have fallen (increased) most relative to other industries. A change in the industry structure of an economy, perhaps due to changing demand or government policies, can lead to changes in the demands for and prices of inputs when the factor intensities of industries differ.

Key Terms

Complementary factors
Effective factor endowment
Effective factor price
Elasticity of factor mobility, σ_F
Factor endowment
Factor mobility
Factor price
Factor productivity
Factor unemployment
Immobile (sector-specific) factors

Long run
Medium run
Mobile factors
Partially mobile factors
Short run
Structural change
Substitute factors
Total factor productivity

PRACTICE AND REVIEW

1. Provide real life examples of an industry with a fully mobile factor and an industry with an immobile factor. In a graph, describe and compare their supply curves and the effects of an increase in demand for their products on their output price and quantity.
2. Assume that you are an industry analyst for manufacturers who build the capital equipment used in the manufacture of computer chips. You have been asked to develop and represent an industry viewpoint on a government-funded training program for engineers who can design and produce the chips using your equipment. Explain whether the engineers and your equipment are substitutes or complements in the production of computer chips. Prepare a graph that describes the effects of the training program on the output and price of your computer chip equipment and write a short paragraph explaining your industry's position.
3. Referring to the U.S. 3x3 structure table (Table 3.4), which industries are most labor-intensive? What are the shares of each production activity in the employment of labor? Based on this information, how do you think that an increase in the production of services in the United States will affect wages and the labor/capital ratios in the three production activities?