8

Taxes in a CGE Model

This chapter examines the treatment of trade and domestic taxes in a computable general equilibrium (CGE) model. Trade taxes are imposed on imports and exports of goods and services. Domestic taxes are taxes paid by production activities on output and factor use and by purchasers on sales of intermediate and retail goods, and income taxes. We trace the tax data in a Social Accounting Matrix (SAM) to describe the agent and the economic activity on which the tax is levied and the amount of revenue generated by each tax; we also show how to use the SAM's data to calculate tax rates. Simple partial equilibrium diagrams then illustrate the theoretical effects of taxes on economic activity and economic efficiency. The results of tax policy experiments using a CGE model support the theoretical predictions and offer additional insight into their economywide effects.

The large federal deficit in the United States in 2011 has spurred intense debate on whether the sizeable tax cuts enacted by the previous administration should be maintained or allowed to lapse. Taxes influence the behavior of an economy's consumers and producers in important ways. CGE models have proven to be a valuable tool for researchers in empirically and comprehensively analyzing how taxes affect households' and firms' economic decisions, and therefore the economy as a whole.

Governments impose taxes for many reasons. Foremost is the need to raise revenue to support the provision of public goods such as national defense and education. Governments sometimes use taxes to redress market failures such as externalities. For example, the government may impose carbon taxes to reduce the harm to public health that is associated with air pollution by private industry. Governments may impose "sin taxes" on goods or activities such as alcohol, tobacco, and gambling to discourage private behaviors deemed to be socially offensive or costly. Most governments tax imports to protect or promote selected industries, and sometimes they tax exports. Governments also use taxes to achieve societal goals, such as income equality. In this case, governments redistribute income by imposing high taxes on high-income households while giving tax credits or income transfers to low-income households.

Taxes impose burdens on the private sector. The ***direct burden*** of a tax is the amount of tax revenue that it generates. A 5 percent sales tax on groceries, for example, imposes a direct burden of five cents for every dollar spent on groceries. The direct burden of taxation is not a loss to the economy because each tax dollar is a transfer of spending power from the tax payer to the government, absent any administrative costs.

Taxes deserve special scrutiny because they often lead to an ***excess burden***, which is the loss in economic efficiency when producers and consumers change the quantities that they produce or consume in order to avoid paying a tax. For example, the 5 percent sales tax on groceries may cause consumers to buy fewer groceries and more of other, untaxed goods that they enjoy less. The change in their consumption bundle is inefficient, given the nation's productive resources and consumer preferences. Tax-distorted consumption and production are an excess burden of taxes that is above and beyond the direct burden of paying the tax. Economists call these inefficiencies a ***deadweight loss*** because these foregone opportunities are not recouped elsewhere in the economy.

CGE models are especially useful for tax policy analysis because they can quantify both the direct (tax revenue) and excess (efficiency effects) burdens of taxes. Because the models are economywide, they also capture potential interactions among all taxes in an economy. This is important because governments typically impose many types and levels of taxes at the same time. Sometimes a tax or subsidy is actually beneficial, in the sense that it offsets the inefficiencies caused by another tax. For example, the introduction of a production subsidy to manufacturers may offset efficiency losses that result from a sales tax on their purchases of inputs. Of course, the overall impact of taxes on an economy also depends on the gains to society from the government spending that is funded by the tax. Keep in mind that societal gains, such as national security or cleaner air, are not readily monetized or generally accounted for in a typical CGE model, unless the economist adapts the model for that purpose.

We categorize taxes into five broad types for the discussion that follows:

- *Trade taxes* are levied on imports and exports.
- *Production taxes* are paid by production activities based on their output.
- *Sales taxes* are paid by domestic firms on their intermediate input purchases, and by consumers and investors on their purchases of final goods and services.
- *Factor use taxes* are paid by production activities based on their factor inputs.
- *Income taxes* are paid by factors or households based on income earned from wages and rents.

The first four taxes are ***indirect taxes*** because they are levied on the production or purchase of goods or factors. By comparison, ***direct taxes***, primarily income taxes, are levied on factors or individuals. Indirect taxes are also distinguished from direct taxes because their burden potentially can be shifted onto someone else, which is not possible with direct taxes. ***Tax incidence*** describes how the burden of paying for indirect taxes is shared among buyers and sellers after prices and wages adjust. For example, when a firm pays a tax to the government based on the value or quantity of its output (a production tax), the tax burden may be shifted, in whole or in part, to consumers, by charging higher retail prices. Individuals cannot similarly shift their income tax burden to others.

For each of the five taxes, we first trace the relevant data in the SAM. A review of the tax data is a useful starting point for any CGE-based tax analysis because the SAM identifies the agent in the model who pays the tax and the production or consumption decision on which the tax is assumed to be levied. For example, a tax on land use that is reported in agriculture's production activity column is paid by the producer and it increases farmers' costs of production. Raising or lowering that tax will directly affect producers' level of output (shifting their supply curve left or right). However, if that same land tax is instead recorded as an expense in the land factor's column, then it is a direct tax, much the same as Social Security or other transfer payments. Raising or lowering the tax will affect households' after-tax income and consumer demand. Placement of tax data in the SAM therefore reveals a great deal about how the tax is assumed to affect economic activity in the CGE model. Economists sometimes have stiff debates over how to represent a particular tax in a CGE model because this decision, similar to model closure rules, predetermines model outcomes.

We focus next on the economic analysis of taxes in a CGE model. We begin by developing simple partial equilibrium theories on taxation that help us to formulate our expectations about the effect of each tax in our general equilibrium model. Graphical analyses of trade taxes include their terms-of-trade effects but analyses of other taxes assume closed or small economies, with no terms-of-trade changes. These graphical analyses emphasize the direct burden (i.e., tax revenues) and the excess burden (i.e., the efficiency losses) associated with most taxes. The excess burdens appear in the graphs as "Harberger triangles," named after the economist, Alfred Harberger (1964), who refined this approach to measuring the efficiency waste caused by taxes.

With this foundation in data and theory, we are equipped to explore the effects of each type of tax in a CGE model. We start by creating a distortion-free version of the U.S. 3x3 CGE model, to provide a baseline or benchmark

Text Box 8.1. Welfare Decomposition in the GTAP Model
Decomposing Welfare Changes in the GTAP Model. (Huff and Hertel, 2000; McDougall, 2006).

The GTAP model contains a utility developed by Huff and Hertel (2000) and McDougall (2003) that decomposes the sources of the total, equivalent variation welfare effect of model experiments. The welfare effect is a money metric measure of the value of the effects of price changes on real consumption and savings in a region. Its decomposition allows a researcher to identify welfare contributions by commodity, factor, and tax type, and to account for second-best effects. The decomposition describes these six components:

- *allocative efficiency effect* – the excess burden of each tax;
- *endowment effect* – due to changes in quantities of factors of production (e.g., labor and capital), which change an economy's productive capacity;
- *technology effect* – due to changes in the productivity of factors and/or intermediate inputs, which change an economy's effective endowments and productive capacity;
- *commodity terms of-trade effect* – due to changes in the economy's world (*fob*) prices of exported goods and services relative to its world (*fob*) prices of imported goods and services;
- *investment-savings terms-of-trade effect* – due to a change in the price of domestically produced capital investment goods relative to the price of savings in the global bank; and
- *preference change effect* – due to changes in the shares of private consumption, government, and savings in national spending.

for our analysis. A distortion-free base model allows us to isolate the effects of each tax without the complexities that its interactions with other taxes in the economy can introduce. We then introduce each individual tax as a shock to this model and compare the model results to our theoretical predictions. Our discussion of model results focuses first on those variables that we highlight in our partial equilibrium analyses. Then, we consider selected general equilibrium results. Although these differ somewhat for each tax, we generally emphasize changes in the commodity composition of consumer baskets, industry output and trade flows, and in the terms of trade and national welfare (see Text Box 8.1).

Last, we return to our original U.S. 3x3 database and CGE model, in which there are many existing tax distortions. Tax experiments using this more realistic model allow us to explore how taxes interact and lead to second best outcomes. We also study the welfare effects of a small change in a complex tax system.

Table 8.1. *Import Tariffs and Imports From The U.S. 3x3 SAM*

Data in $U.S. Billion or Percent	Agriculture	Manufactures	Services
Import tariff revenue	1	24	0
Imports (value in *fob* prices)	167	1203	230
Import trade margins	9	47	0
Import tariff rate	0.5	1.9	0.0

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

Trade Taxes

Import Tariffs

Import tariffs are taxes that are levied on the quantity or value of imported goods and services. Import tariffs are levied in one of two ways. ***Specific*** tariffs are paid per unit of import, such as $1 dollar per barrel of oil. Specific tariff payments grow in proportion to quantity, so that the import tariff on two barrels would cost $2 dollars and the tariff on three barrels would cost $3 dollars, and so on. Specific tariff payments do not change when prices change; for example, the importer pays $1 dollar per barrel regardless of whether oil costs $25 or $125.

Ad valorem tariffs are levied as a percentage of the *cif* import value (which includes trade margin costs). For example, a 5 percent *ad valorem* import tariff on a handkerchief with an import value of $1 increases its cost to $1.05. If the hanky's *cif* import value increases to $2, its cost, including the tariff, would be $2.10. In this case, tariff revenue for the single handkerchief increases from five cents to ten cents following the change in its price.

Import tariffs are paid by the import varieties of the commodity columns of the SAM to the import tariff row account. The tariff increases the cost of imported goods so all categories of intermediate and final demand that consume imports ultimately pay the tariff. Table 8.1 reports the import tariff revenue and the value of imports from the U.S. 3x3 SAM. We calculate *ad valorem* import tariff rates as:

import tariff revenue/*cif* value of imports * 100.

The U.S. *ad valorem* tariff rate on agriculture is therefore:

$$\$1 \text{ billion}/(\$167 \text{ billion} + \$9 \text{ billion}) * 100$$
$$= 0.5 \text{ percent (adjusted for rounding)}$$

The U.S. tariff rate is highest on imports of manufactured goods (1.9 percent) and lowest on services (approximately zero).

Figure 8.1 illustrates the economic effects an *ad valorem* import tariff on a large economy. In the figure, S describes the foreign supply of the imported

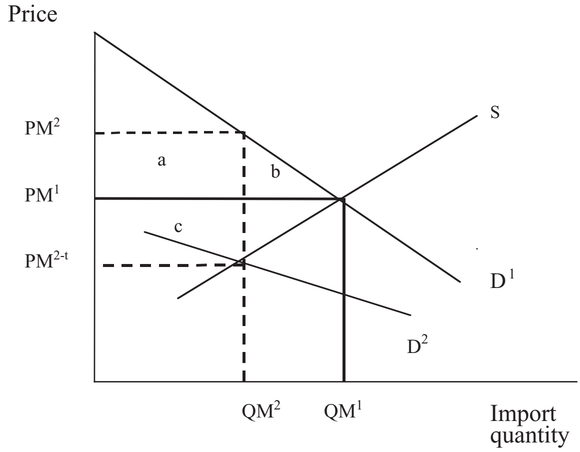

Figure 8.1. Effects of an import tariff on the importer

good. Given the Armington assumption that goods are differentiated by country of origin, there is no domestic production of the imported variety. D^1 is a compensated demand curve that describes the duty-free demand for imports by domestic consumers.[1] In the initial market equilibrium, the *cif* price of imports is PM^1 and the import quantity is QM^1.

The introduction of an import tariff adds an additional cost, *t*, to the import price, which shifts the demand curve downward to D^2. In the new equilibrium, consumers pay a higher domestic price of PM^2, which is the *cif* world import price plus the tariff, *t;* the import quantity declines to QM^2; and the import price net of the tariff falls to PM^{2-t}.

The tariff has three effects on the importing country. The direct burden of the tariff, shown as area $a + c$, is the amount of tariff revenue paid by consumers to the government on imports of quantity QM^2. Tariff revenue redistributes purchasing power from consumers to the government, so this area is not a loss to the economy.

The second effect is the excess burden on the importer, shown as area *b.* It represents a consumption inefficiency because consumers who would have been willing to purchase QM^1-QM^2 imports at the free market price no longer can do so. The difference between the price that consumers are willing to pay and the market price is the consumer's "surplus." For example,

[1] This type of demand curve implies that the government compensates consumers dollar for dollar for their tariff expenditure, either through a lump-sum transfer of income or other mechanism. This compensation assumption is common in tax policy analysis. It allows economists to attribute all quantity changes to the substitution effect (which is the excess burden) because the compensation cancels any income effects of the tax. In other words, this approach keeps the consumer on the same indifference curve by holding income constant and describes only the substitution along the curve when the tax changes relative prices. See Ballard and Fullerton (1992) for a survey of this approach in the economics literature and Technical Appendix 8.1 for more details.

at QM^2, a consumer who would have been willing to pay PM^2 actually paid only PM^1 at free trade prices, and so gained a surplus on that unit of $PM^2 - PM^1$. The sum of the surpluses enjoyed by consumers on all units up to QM^1, purchased at free trade prices, is the triangular area between PM^1 and D^1. The trapezoid formed by areas *a* plus *b* is the sum of the consumer surplus that is lost when consumers reduce their import consumption to QM^2 and pay the higher price of PM^2. Because the foregone surplus shown by area *a* is transferred to the government as a part of the tax revenue, the remaining area, *b*, is the loss in consumer surplus that is not recouped elsewhere in the economy.

For large countries, there may also be terms-of-trade effects as described by area *c*. Our example in Figure 8.1 shows a terms-of-trade gain for the importer because the decline in its import demand causes the import price, excluding the tariff, to fall from PM^1 to PM^{2-t}. The size of its terms-of-trade gain depends on the slope of the import supply curve. In general, the lower the foreign export supply elasticity (i.e., the steeper is the slope of the import supply curve), the larger the importer's terms-of-trade gain from a tariff. If the importing country is too small in the exporter's market to affect its export price, then the foreign supply curve is horizontal. In this case, the import price remains at PM^1 and there is no terms-of-trade effect.

The terms-of-trade effect, like the direct burden, redistributes purchasing power. In this case, purchasing power is redistributed from foreigners to domestic consumers. In effect, the lower price accepted by foreigners compensates consumers for area *c* of their tariff payment to the government so the domestic price increases by less than the full amount of the tariff. The terms-of-trade gain to the importer, area *c,* is a loss of import purchasing power by the exporting country.

Because tax revenue simply redistributes national income, the change in national welfare includes only the excess burden, or efficiency effect, of the tariff plus its terms-of-trade effect. Therefore, the net effect on the importer's welfare depends on whether its consumption efficiency loss, shown by area *b,* is greater than its terms-of-trade gain, area *c*. The effect on the exporter's welfare is unambiguously a loss, shown by its terms-of-trade decline, area *c.*

The figure also illustrates how tariffs diminish global welfare. The loss in global welfare is the sum of countries' efficiency losses, shown in our case as the importer's area *b*. Terms-of-trade effects are not included in a measure of global welfare. Because one country's terms-of-trade loss is equal to its partner's terms-of-trade gain, this price effect just redistributes purchasing power among countries, similar to the domestic redistribution of tariff revenue. Redistribution does not affect global welfare as long as we assume – as we do in standard CGE models – that income has the same value, regardless of its distribution among consumers, governments or countries. In a more sophisticated analysis, we might choose to relax this assumption to reflect

Table 8.2. *Effects of 15 Percent Import Tariff on Manufacturing Imports to the United States*

U.S. manufacturing	
Tariff revenue (\$U.S. billion) (NETAXES)	134.7
Import quantity (*qiw*) (% change)	–20.1
Bilateral import price from ROW (% change) ($pfob_{ROW}$)	–1.3
Terms of trade (% change) ($pfob_{US}-pfob_{ROW}$)	5.6
Domestic market price of import (% change) (*pim*)	13.6
Efficiency effect. (U.S. \$billion)	–15.6
Welfare (\$U.S. billion)	
U.S. welfare	54.9
Rest-of-world welfare	–73.1
World welfare	–18.2
Selected general equilibrium effects in United States (% change)	
Bilateral export price of mfg, to ROW ($pfob_{US}$)	4.3
Factor price exchange rate (*pfactor*)	3.5
Exports of agriculture (*qxw*)	–22.5
Exports of manufactures (*qxw*)	–29.6
Exports of services (*qxw*)	–15.8

Source: GTAP model, U.S. 3x3 v.7.0 with taxes removed to create a distortion-free base model.

different valuations across market participants, depending, for example, on their initial levels of income. Arguably, another dollar might mean more to consumers in countries with very few dollars to start with than it does to someone who has a great many.

By studying the theory of import tariffs before we carry out a CGE model experiment, we can identify the results that are most relevant to consider and to report in our discussion, and we can develop expectations about their direction of change. With this foundation, we are ready to study a CGE analysis of the introduction of an import tariff in one industry. Our experiment is the introduction of a 15 percent import tariff by the United States on imports of manufactures. For this and most other tax experiments, we use the Global Trade Analysis Project (GTAP) model with a distortion-free U.S. 3x3 database.[2]

Results of the import tariff experiment, reported in Table 8.2, are consistent with the qualitative results shown in Figure 8.1. A contribution of our CGE model analysis is that it enables us to quantify these impacts. The tariff's direct burden is the import tariff revenue for the U.S. government of \$135 billion. The quantity of U.S. manufacturing imports fall by 20 percent, contributing to a terms-of-trade gain for the United States as its import price falls by 1.3 percent. As a result, the domestic price of imports increases by less than

[2] We create a distortion-free base model using GTAP's Altertax utility to update all U.S. taxes and subsidies in the U.S. 3x3 model to zero.

the full amount of the tariff. The excess burden, or deadweight efficiency loss, related to manufacturing totals $15.6 billion dollars.

Our CGE analysis also takes into account general equilibrium effects that lie outside the scope of our theoretical, partial equilibrium model. First, we consider the manufacturing terms-of-trade effect. Recall from our discussion in Chapter 6 that the terms of trade depends on changes in both the import and export price. Our CGE-based analysis finds that the U.S. import tariff increases domestic demand for the U.S. variety and causes U.S. manufactured exports to fall by almost 30 percent. This results in a 4.3 percent increase in the U.S. *fob* world export price for manufactures. Thus, changes in *both* the U.S. import and export prices account for the nearly 6 percent improvement in the U.S. terms of trade in manufactures.

The import tariff on manufactured goods affects U.S. industry structure because an expanding manufacturing sector competes with other industries for productive resources. This competition causes U.S. wages and rents to rise relative to those in the rest-of-world. This is similar to a real exchange rate appreciation and it makes all U.S. goods relatively expensive on world markets. Both resource competition and real appreciation contribute to a decline in U.S. production and exports of agriculture and services, and an increase in U.S. imports of these goods. These changes in trade flows, too, contribute to an aggregate U.S. terms-of-trade gain and a total U.S. welfare gain of $55 billion. World welfare, which measures the efficiency losses due to the tariff, declines by more than $18 billion.

Export Taxes

Export taxes lower the price received by the producer on sales to the world market. Countries sometimes impose export taxes to ensure that adequate supplies of vital goods, such as foodstuffs or strategic minerals, remain available for the home market. For example, if a producer sells wheat for $1 per bushel in both the domestic market and foreign markets, a 10 percent export tax will lower his export price to ninety cents. An export tax therefore encourages producers to shift their sales from the export market to the domestic market – or to shift into the production of other goods and services.

Export taxes are reported in the SAM as an expenditure from the domestic variety of the commodity column account to the export tax row. Exports in *fob* prices, which include export taxes, are reported in the rest-of-world column account as a purchase from the domestic commodity account row. Data in the U.S. 3x3 SAM report an export tax of $2 billion on U.S. manufacturing exports of $756 billion.

We calculate the export tax or subsidy rate as:

$$\text{Export tax revenue/value of export in world } fob \text{ price} * 100$$

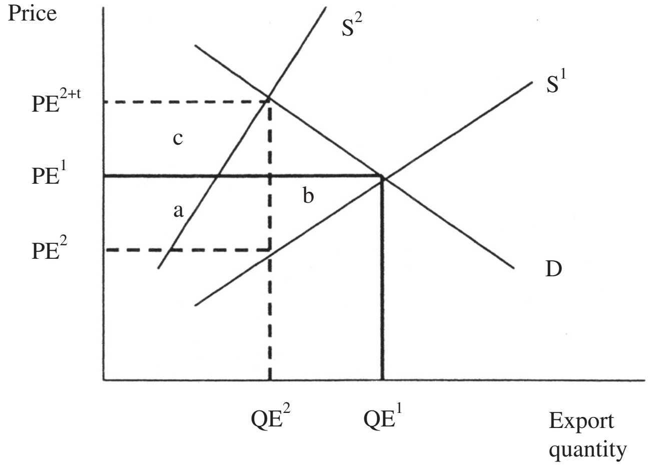

Figure 8.2. Effects of an export tax on the exporter

For example, the export tax rate on U.S. manufacturing exports is:

$$\$2/\$756 \text{ billion} * 100 = 0.3 \text{ percent}$$

Figure 8.2 illustrates the market effects of an *ad valorem* export tax. Although the graph looks similar to Figure 8.1, note carefully that the definitions of the supply and demand curves are different. In this case, S^1 describes the home country's supply of exports to the world market. Because we assume that products are differentiated by country of destination, there is no domestic demand for the export variety. D describes foreign demand for the home country's exports, QE. In the initial equilibrium, quantity QE^1 is exported at the *fob* export price of PE^1. The introduction of an export tax lowers the producer price to PE^2, and shifts the export supply curve backward to S^2. In the new equilibrium, export sales decline to QE^2 and foreign buyers pay price PE^{2+t}.

Similar to import tariffs, export taxes have three effects on the exporting country. The direct burden is the amount of export tax revenue that is transferred from producers to the government, shown as area $a + c$. The excess burden, or efficiency effect, in the exporting country is described by area b. Production is inefficient because the marginal cost of producing the foregone output $QE^1 - QE^2$, shown by the pretax supply curve, is less than the price that foreigners are willing to pay. Another way to think about it is that, before the tax, the marginal cost to produce QE^2 was PE^2 but producers sold it for PE^1, gaining a producer "surplus" for that unit of $PE^1 - PE^2$. The sum of these surpluses over all units of production up to QE^1 is total producer surplus, shown by the triangular area between PE^1 and S^1. The tax causes producers to lose producer surplus described by the trapezoid area of $a + b$. Area a is transferred to the government as tax revenue but area b is a deadweight loss, in excess of the tax burden, that is not recouped elsewhere in the economy.

Table 8.3. *Effects of 15 Percent Export Tax on U.S. Manufactures*

U.S. Manufacturing	
Tariff revenue ($U.S. billion) (NETAXES)	67.6
Efficiency effect (U.S. $billion)	–26.1
Export quantity (*qxw*) (% change)	–44.8
Producer price (*ps*) (% change)	–4.4
Production (*qo*) (% change)	–4.8
World export price ($pfob_{US}$) (% change)	12.7
Terms of trade (% change) ($pfob_{US} - pfob_{ROW}$)	13.9
Welfare ($U.S. billion)	
U.S. welfare	–22.6
Rest-of-world welfare	–1.9
World welfare	–24.5
Selected general equilibrium effects in the United States (% change)	
World (*fob*) import price ($pfob_{ROW}$) (% change)	–1.3
Import quantity of manufacturing (*qiw*)	–18.0
Export quantity of agriculture (*qxw*)	42.6
Exports quantity of services (*qxw*)	29.4
Factor price exchange rate (*pfactor*)	–5.7

Source: GTAP model, U.S. 3x3 v.7.0 with taxes removed to create a distortion-free base model.

The third effect is the terms-of-trade gain, area *c*, which measures the redistribution of purchasing power from foreigners to domestic producers because the reduction in export supply causes the export price to rise from PE^1 to PE^{2+t}. This transfer compensates producers for part of their revenue transfer to the government; in effect, producers have passed on part of the export tax burden to foreign importers through an increase in their export price. In this case, we assume a large country exporter, consistent with the Armington assumption that every country is large country in its export market. A small country (as in many single-country CGE models) would face a horizontal world demand curve, and the producer's price would fall by the full amount of the export tax.

The net effect on the exporter's welfare depends on whether its efficiency loss, area *b,* is larger than its terms-of-trade gain, area *c*. The effect on the importing country's welfare is unambiguously a loss, shown by area *c.* The loss in global welfare, too, is unambiguously negative; it is the sum of all countries' efficiency losses, which in this case is area *b.*

To explore the effects of an export tax on one industry in a CGE model, we use the GTAP model with the distortion-free U.S. 3x3 database to run an experiment that introduces a 15 percent export tax on U.S. manufacturing. We find a direct burden, the export tax revenue, of $67.6 billion and an excess burden, the efficiency loss in manufacturing, of $26.1 billion (Table 8.3). The

Table 8.4. *Production Taxes in The U.S. 3x3 SAM ($U.S. billions)*

	Agriculture	Manufactures	Services
Production tax	4	42	423
Gross value of production	434	5,227	14,974
Production tax rate	1.0	0.8	2.8

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

U.S. export quantity falls almost 45 percent, but this yields a U.S. terms-of-trade gain in manufacturing. The U.S. world export price increases nearly 13 percent, so the producer price falls by only 4.4 percent

Our general equilibrium model yields additional insights into the effect of the tax. Because most are the mirror image of the effects of the import tariff, we leave it as an exercise for you to explain the effects of a decline in U.S. manufacturing production and exports on industry structure, trade flows, U.S. terms of trade, and U.S. and world welfare.

Production Taxes

Producers pay production taxes on the basis of the value or quantity of their output. These taxes are a part of their costs of production. For example, U.S. companies engaged in oil and natural gas production pay a wide variety of production-based taxes to state, federal, and local governments. These taxes raise their production costs. Production taxes can also be negative (i.e., subsidies). For example, many countries provide tax credits or direct subsidies based on the production of agricultural products.

In the SAM, the production activities' column accounts pay these taxes to the production tax row account. Table 8.4 displays these row and column accounts from the U.S. 3x3 SAM.

We calculate production tax rates (or subsidies) as:

$$\text{Production tax/gross value of production} * 100.$$

For example, the production tax rate for U.S. services is:

$$423/14{,}974 * 100 = 2.8.\ \text{percent}$$

Figure 8.3a illustrates the market effects of an *ad valorem* production tax. In the figure, the initial market supply curve, S_1, describes domestic production and the compensated demand curve, D, describes consumer demand. P^1 and QO^1 are the initial market equilibrium price and quantity, respectively. The introduction of a production tax shifts the industry supply curve inward to S^2. This results in a higher market equilibrium price P^{2+t} for consumers, a

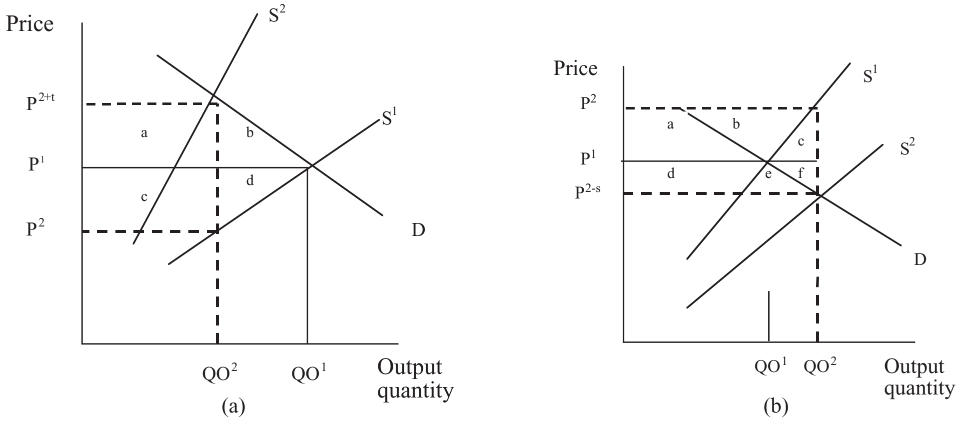

Figure 8.3.(a) Market effects of a production tax. (b) Market effects of a production subsidy

lower after-tax price for producers, P^2, and a fall in the equilibrium quantity of supply and demand to QO^2.

The direct burden of the production tax is area $a + c$, which is the tax revenue paid by producers to the government. Areas $a + b$ are the loss of consumer surplus and areas $c + d$ are the loss of producer surplus due to the tax. Because areas $a + c$ are recouped by the government as tax revenue, the excess burden is the combined loss in consumption efficiency, area *b,* and production efficiency, area *d.*

Areas *a* and *c* also describe the incidence of the production tax. The figure illustrates that, although producers actually pay the tax, the burden of paying for it is shared with consumers because producers have been able to raise their (gross of tax) sales price from P^1 to P^{2+t}. As you can see from the figure, the size of the tax revenue and its incidence are determined by the slopes of the supply and demand curves, which in turn are determined by the elasticities of supply and demand. If demand is perfectly elastic (a horizontal demand curve), then the consumer price would remain at P^1 and producers would absorb the full cost of the tax. If supply is perfectly elastic (a horizontal supply curve), then consumers would absorb the full cost of the tax.

Many countries subsidize rather than tax their producers. The analysis of a production subsidy differs in some respects from the analysis of a tax. In Figure 8.3b, the introduction of an *ad valorem* output subsidy shifts the supply curve outward to S^2. The new equilibrium output increases to QO^2, the consumer price falls to P^{2-s}, and the price received by producers increases to P^2.

In the case of a subsidy, the direct burden falls on the government because the subsidy is a transfer from the government to producers and consumers, instead of tax revenue for the government. In the figure, government spending is the sum of areas $a + b + c + d + e + f$. However, the subsidy increases

Table 8.5. *Effects of a 15 Percent Production Tax on U.S. Manufactures*

Manufacturing (% change from base)	
Production tax revenue (NETAXES)	655.0
Efficiency losses in mfg.	60.2
Production quantity (*qo*)	−15.0
Private household demand (*qpd*)	−19.0
Producer price (*ps*)	−3.2
Private household consumer price (*ppd*)	12.9
Selected general equilibrium results (% change from base)	
Manufacturing export quantity (*qxw*)	−32.1
Manufacturing import quantity (*qiw*)	6.4
Terms of trade in manufacturing ($pfob_{US} - pfob_{ROW}$)	6.7
Wages (*pfe*)	−15.4
Capital Rents (*pfe*)	−15.1
Agricultural production (*qo*)	13.2
Services production (*qo*)	2.7
Welfare ($U.S. billion) (EV)	−121.3

Source: GTAP model, U.S. 3x3 v.7.0 with taxes removed to create a distortion-free base model.

consumer surplus only by areas $d + e$ and increases producer surplus only by areas $a + b$. The increased quantity of production and consumption is inefficient because at quantities that exceed QO^1, the marginal benefit to consumers of each additional unit is less than the marginal cost of its production. This inefficiency is described by areas $c + f$, which is the excess burden of the subsidy.

With these insights from our partial equilibrium models, we turn to an examination of the effects of a production tax in one industry in a CGE model. Our experiment is the introduction of a 15 percent production tax on U.S. manufacturing output. We find that the direct burden is the manufacturing production tax revenue of $655 billion and the excess burden is a $60 billion loss in efficiency due to a 15 percent decline in manufacturing output and a 19 percent decline in consumer demand (Table 8.5). The 3.2 percent fall in the producer price and the 13 percent increase in the consumer price tell us that the tax burden has been shared between U.S. producers and consumers, but that most has been passed on to consumers.

Our CGE model also describes the general equilibrium effects of the tax. In the manufacturing sector, lower domestic production reduces its demand for inputs and causes economywide wages and rents to fall. Lower factor prices encourage agricultural and services production and exports to increase. Manufactured exports decline sharply, causing the manufacturing terms of trade improve. The total U.S. welfare effect, which combines efficiency loss and all terms-of-trade effects is a loss of $121 billion.

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Table 8.6. *Sales Taxes on Household Purchases of Domestically Produced Variety*

	Household
Purchases ($U.S. billion)	
Agriculture	60
Manufactures	1,104
Services	6,392
Sales tax ($U.S. billion)	
Agriculture	2
Manufactures	115
Services	41
Sales tax rate (%)	
Agriculture	4
Manufactures	10
Services	1

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

Sales (and Intermediate Input) Taxes

Sales taxes are paid by domestic final demand (households, investment, and sometimes government) on purchases of commodities used for consumption or investment. Production activities pay sales taxes on their purchases of intermediate inputs. The sales taxes are a part of their cost of production. Foreigners do not pay other countries' sales taxes, so a country's exports do not generate sales tax revenue.

In many countries, sales tax rates vary by commodity and type of buyer. In the United States, for example, consumers usually pay sizeable sales taxes on their purchases of autos but often pay little or no sales tax on their grocery purchases. Private household consumers pay sales taxes on many products while sales taxes on these same goods are waived for entities like churches and other nonprofit organizations. Negative sales taxes, like other negative taxes in the SAM, denote subsidies. They reduce the cost of a purchase. Some common examples of subsidies are food stamps, which low-income households can apply to their food purchases, or rebates on farmers' purchases of intermediate inputs, like fertilizer.

The SAM reports sales taxes as a payment from the column account of the purchaser to the sales tax row account for each purchased good. As an example, Table 8.6 reports data from the U.S. 3x3 SAM on private households' sales taxes on their purchase of the domestically produced variety of each commodity. These total $158 billion ($2 billion + $115 billion + $41 billion) on purchases of agriculture, manufactures, and services.

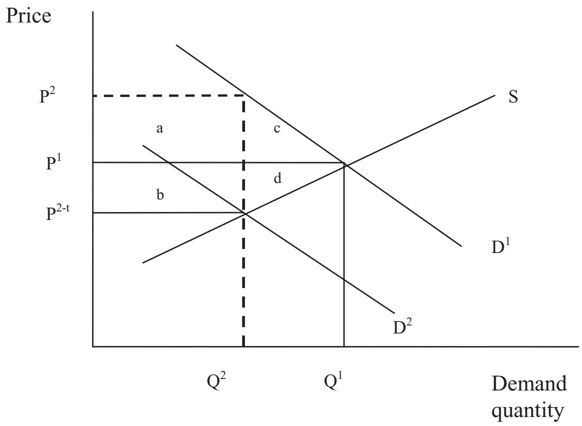

Figure 8.4. Effects of a sales tax on the domestic market

Sales tax rates are calculated as the ratio of the tax to the pretax value of the sale:

$$\text{commodity sales tax/pretax value of commodity purchase} * 100.$$

For example, the tax rate on households' purchases of domestic manufactured goods is calculated as:

$$115/1{,}104 * 100 = 10.4 \text{ percent}.$$

Firms' payment of a sales tax or their receipt of a subsidy on purchases of intermediate inputs are called an intermediate input tax or subsidy. The effects of input taxes or subsidies on the output of a firm are identical to those of a production tax or subsidy, shown in Figures 8.3a and 8.3b, so we do not reproduce that analysis here.[3]

Figure 8.4 describes the effect of a specific (per unit) sales tax on the domestic supply and compensated demand for a final good, Q. In the figure, D^1 is the initial compensated demand curve and S is the supply curve for the domestic production of Q that is sold in the domestic market. Q^1 is the initial market equilibrium quantity, and P^1 is the initial market equilibrium price. The sales tax shifts the demand curve inward to D^2. The new market equilibrium is at quantity Q^2 where consumers pay the tax-inclusive sales price of P^2 and producers receive price P^{2-t}.

The direct burden of the tax is shown by area $a + b$, which is the amount of sales tax revenue collected by the government on sales of Q^2. Although the tax is paid by consumers, the figure shows that the burden is shared with producers due to the decline in the producer price from P^1 to P^{2-t}. The excess burden of the tax, described by areas $c + d$, measures the loss in

[3] The effects are identical if we assume fixed Leontief intermediate input-output coefficients, which is a common assumption in CGE models.

Table 8.7. *Effects of 15 Percent Sales Tax Rate on Household Purchases of the Domestic Manufacturing Commodity*

U.S. Manufacturing	
Sales tax revenue ($U.S. billion)	122.6
Efficiency loss ($U.S. billion)	12.9
Household consumption (*qpd*) (% change)	−17.9
Production quantity (*qo*) (% change)	−2.8
Consumer price (*pd*) (% change)	14.1
Producer price (*ps*) (% change)	−0.8
Selected general equilibrium effects	
Agriculture domestic sales (% change) (*qpd*)	0.5
Manufacturing domestic sales (% change) (*qpd*)	−4.7
Services domestic sales (% change) (*qpd*)	0.8
Agricultural production (*qo*)	0.6
Services production (*qo*)	0.6
Manufacturing export quantity (*qxw*)	7.5
Manufacturing import quantity (*qiw*)	5.6
U.S. welfare ($U.S. billion)	−29.7

Source: GTAP model, GTAP v.7.0 U.S. 3x3 database with taxes removed to create a distortion-free base model.

consumer and producer surplus as the market equilibrium quantity falls by $Q^1 - Q^2$. The decline in consumption and production is inefficient because the marginal benefit to consumers of each additional unit between $Q^1 - Q^2$ exceeds its marginal cost of production.

To explore the effects of a sales tax on one commodity in a CGE model, we carry out an experiment that imposes a 15 percent sales tax on households' purchases of the domestic variety of the manufactured commodity. We use the GTAP CGE model with the distortion-free U.S. 3x3 database. We find that the direct burden of the sales tax is a tax revenue of $123 billion (Table 8.7). Its excess burden is an efficiency loss in manufacturing of nearly $13 billion as both the quantity of household demand and production fall. The consumer price increases by nearly the full amount of the tax but the producer price declines only slightly – indicating that U.S. consumers bear most of the burden of the tax.

Once again, we also consider selected general equilibrium effects of the tax. For this tax, we focus on the role of demand shifts in influencing industry structure. The sales tax changes the relative prices of consumer goods, causing private households to change the commodity composition of their baskets. When they reduce their consumption of domestic manufactures, they increase their consumption of domestically produced agriculture and services. Production in these two sectors therefore increases as manufacturing output falls.

Table 8.8. *Factor Use Taxes in the United States in Agriculture and Manufacturing*

	Agriculture	Manufacturing
Factor payment ($U.S. billion)		
Land	34	0
Labor	68	1,109
Capital	122	467
Factor use tax ($U.S. billion)		
Land	−3	0
Labor	5	166
Capital	−1	15
Factor use tax rate (%)		
Land.	−9	0
Labor	7	15
Capital	−1	3

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

Trade flows are also an important part of this tax's impacts. On the import side, the sales tax on the domestic variety causes the imported variety to become relatively cheaper, which increases the quantity of manufactured imports demanded by U.S. households. On the export side, the fall in U.S. demand for the domestic supply increases the quantity available for export; causing exports to rise. The changes in both trade flows contribute to a decline in the U.S. terms of trade in manufacturing. U.S. terms of trade in the other two sectors also fall as their production and export supply increase. Total terms-of-trade losses, combined with efficiency losses, cause U.S. welfare to decline by $30 billion due to the sales tax.

Factor Use Taxes

Producers pay taxes or receive subsidies based on the quantity of factors (e.g., labor, capital, and land) that they employ in their production process, or on the value of their factor payments. Data on factor use taxes are reported in the production activity column of the SAM as a payment to the factor use tax row. Factor tax rates are calculated for each factor in each industry as:

$$\text{factor tax/pretax factor payment} * 100.$$

We report these data for the agricultural and manufacturing activities from the U.S. SAM in Table 8.8. For example, in the U.S. 3x3 SAM, the factor tax rate for land used in agriculture is:

$$-3/34 * 100 = -9 \text{ percent.}$$

Note that the rate is negative, which means that U.S. farmers receive a subsidy on land use.

It is not unusual for different governmental entities within the same country to impose simultaneous factor use taxes and subsidies on the same factor. For example, landowners may pay a real estate tax to their state or local government and, if they are farmers using the land for agricultural purposes, they may also receive an acreage-based subsidy, based on the very same parcel of land, from the federal government. Thus, factor use tax data may report the combined costs of different tax programs.

Sometimes factor use taxes are uniform across industries, such as the Social Security tax that is paid as a percentage of wages by all employers in the United States. Uniform factor use taxes or subsidies do not influence the distribution of factor employment across industries. However, it is often the case that factor taxes differ among industries or by use, such as different real estate tax rates for commercial and residential zones. In the U.S. SAM, for example, the 7 percent tax rate on labor used in agriculture, reported in Table 8.8, is lower than the 15 percent tax rate on labor employed in manufacturing. In this case, the factor use tax changes the relative costs of production in the two industries, discouraging employment and production in the industry with the higher tax.

Factor use taxes also typically differ by factor. For example, an industry's corporate tax rate on capital services may be quite high relative to its payroll tax. Tax rates on land, labor, and capital in U.S. agriculture, reported in Table 8.8, illustrate this point. Agriculture's land and capital inputs are subsidized, but its use of labor is taxed. When factor use tax rates differ by factor then – if the production technology allows it – this, too, can lead to a misallocation of factors. Those factors whose employment is taxed will be under-used and those factors that are subsidized will be over-used relative to their most efficient level of employment in each industry.

The effect of a factor use tax on industry output is similar to that of a production tax, as already shown in Figures 8.3a and 8.3b, so we do not replicate that analysis here.[4] Instead, we direct our attention to a general equilibrium analysis of a factor use tax on one factor in one industry on factor use and output in all industries. Figure 8.5 describes the effects of a factor tax – in this case a tax on labor – on the allocation of the workforce in a two-factor, two-sector model. The economy's two sectors are agriculture and manufacturing, and its two factors are labor and capital. In this beaker diagram, a rightward movement from the left origin on the horizontal axis indicates an

[4] Like a production tax, a factor tax increases the cost of production and shifts the supply curve inward. However, a factor use tax can have a smaller impact on production costs than an equivalently-sized production tax if producers can substitute away from the taxed factor within the value-added bundle.

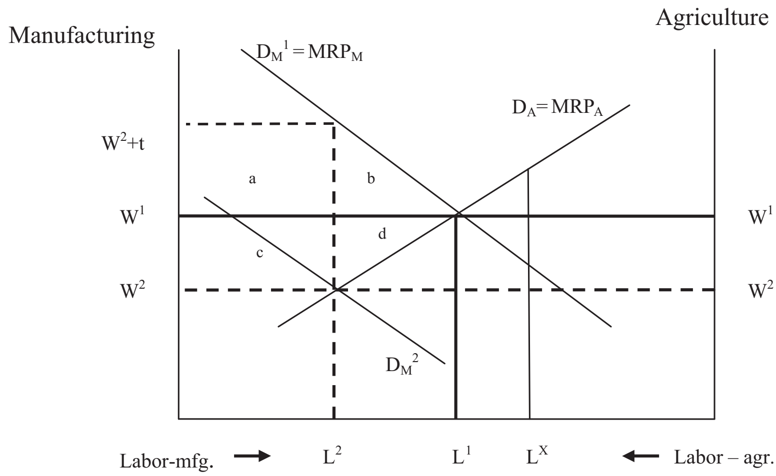

Figure 8.5. Effects of a factor tax on the economywide labor market

increase in the employment of labor in manufacturing and a leftward movement from the right origin describes an increase in the employment of labor in agriculture. Employment in the two sectors sums to L, the total labor force.

An assumption of the model is that labor is fully mobile across the two sectors, but that capital is fixed in each industry at its initial quantity. This assumption means that the theoretical model describes adjustment over a shorter time frame than in the CGE models with fully mobile factors that we mostly have usually used for demonstration. The industry demand curves for labor by the manufacturing ($D_M{}^1$), and agricultural (D_A) sectors are downward sloping. This reflects the assumption that the marginal revenue product (MRP) of labor (the additional revenue earned from the addition of one more worker) declines in both industries as the quantity of labor increases relative to the fixed quantity of capital. The MRP of each industry describes the wage that a firm is willing to pay. For example, as the ratio of farm workers to a fixed number of tractors increases from zero to L, moving leftward on the horizontal axis, the marginal revenue product and wage of each additional farm worker in agriculture gradually falls.

In the initial equilibrium, employment is allocated across the two industries at L^1. This allocation of labor equalizes the wage across the two industries at w^1, the economywide wage. Suppose the economy were not at equilibrium, and instead had a labor allocation such as L^X. At this point, the MRP of labor in agriculture, which is the vertical height of the intersection of L^X and D_A exceeds that in manufacturing. Agriculture's higher wage will attract labor into agriculture. The decline in the ratio of workers to capital in manufacturing will cause an increase in labor's MRP in manufacturing sector and the higher labor-capital ratio in agriculture relative will lower the MRP

Table 8.9. *Effects of a 15 Percent Tax on Labor Used in U.S. Manufacturing*

Effects on Industries (% change from base)	
Employment in manufacturing (*qfe*)	–4.7
Employment in agriculture (*qfe*)	1.8
Employment in services (*qfe*)	0.9
Economywide wage (*ps*)	–5.2
Wage (including tax) in manufacturing (*pfe*)	2.9
Agricultural production (*qo*)	0.6
Manufacturing production (*qo*)	–3.4
Services production (*qo*)	0.7
Government revenue ($U.S. billion) (NETAXES)	159.1
Efficiency loss ($U.S. billion)	–3.4
Welfare (EV) ($U.S. billion)	–24.7

Source: GTAP model, GTAP v.7.0 U.S. 3x3 database with fixed capital stocks and taxes removed to create a distortion-free base model.

of farm labor until the MRP of labor in both industries equalize at L^1 and wage w^1.

The introduction of a specific (per worker) labor use tax in manufacturing shifts manufacturers' after-tax labor demand curve downward, to $D_M{}^2$. As the manufacturing wage falls, labor moves from manufacturing into agricultural employment. At the new equilibrium, the employment allocation is L^2, the economywide wage falls to w^2, and manufacturers pay a wage plus tax of w^{2+t}. The wage is now lower in manufacturing because the tax reduces its demand for labor, and it is lower in agriculture because the increase in its labor force causes the MRP of its workers to decline.

The direct burden of the factor use tax is the sum of rectangles $a + c$, which is the amount of tax revenue generated by the employment of L^2 workers in manufacturing. The excess burden of the tax related to manufacturing is the sum of triangles $b + d$. Labor employment in manufacturing is now inefficiently low because the marginal product of each additional worker between L^2 and L^1 exceeds its marginal cost, measured by curve D_A.

We simulate a factor use tax in one sector in a CGE model by conducting an experiment that introduces a 15 percent tax on labor employed in U.S. manufacturing. We use the GTAP model with the distortion-free U.S. 3x3 database. We assume that the capital stock employed in each industry is fixed, but that labor is fully mobile among sectors. Our CGE model differs from our theoretical model because it has a third factor of production, land. Similar to capital, we assume that a fixed quantity of land is employed in agriculture. For brevity, we do not include land in our discussion of results.

Consistent with our theoretical model, the labor tax raises employers' cost per worker in manufacturing and reduces their labor demand (Table 8.9). In the new equilibrium, manufacturing employment falls by 5 percent. Higher agricultural and services employment, with declining labor productivity in those two industries, also contribute to a decline in the economy-wide wage of more than 5 percent. Yet, manufacturers pay an after-tax wage that is 2.9 percent higher. Increased agricultural and services employment also contribute to a change in the industrial structure of the economy. Agriculture and services output increase while manufacturing output declines.

Our CGE model quantifies the direct and excess burdens illustrated in Figure 8.5. The direct burden of the tax is $159.1 billion. The excess burden, or efficiency effect, in manufacturing is a loss of nearly $4 billion. The national welfare effect includes both the efficiency loss and a deterioration in the U.S. terms of trade, resulting in a total U.S. welfare loss of nearly $25 billion.

Income Taxes

Income taxes, also called direct taxes in CGE models, are paid by factors of production or by households, usually as a percentage of their income from land rents, wages, and capital returns. Income taxes differ in an important respect from the indirect taxes discussed previously. Because they are not imposed directly on goods and services, they do not alter relative market prices. They do not make textiles and apparel more or less expensive than food, for example. Because they do not directly influence relative prices, they therefore are generally less distorting of production and consumption decisions, and therefore of economic efficiency, than indirect taxes.

Income taxes do affect things like after-tax, or net, wage. When income taxes lower net wages, some people may choose to work less and spend more time on leisure activities. A decline in net wages can also motivate some people to work more hours, instead of less, if they need the additional earnings to compensate for the fall in their after-tax income. Income taxes, in addition, affect the rate of return on savings and may cause households to change their allocation of income between consumption and savings. This is an intertemporal distortion because it changes the timing and amount of consumption over a lifetime and the availability of savings for investments in future production. Income taxes also can influence households' investment allocations if tax rates differ among asset classes as they do in the case of interest income and capital gains. For these reasons, income taxes are likely to distort some household decisions.

These impacts of income taxes on labor supply, and on savings and investment decisions, though very important, are not accounted for in the standard CGE model that we are studying. Dynamic, multiperiod CGE models are needed to analyze the intertemporal effects of income taxes, and a labor-supply response must be incorporated to analyze the tax's effects on

Text Box 8.2. U.S. Tax Reform in a Dynamic Overlapping-Generations CGE Model
"Simulating the Dynamic Macroeconomic and Microeconomic Effects of the FAIR Tax." (Jokisch and Kotlikoff, 2005).

What is the research question? The Fair Tax is a proposal to replace the U.S. federal payroll tax, personal income tax, corporate income tax, and estate tax with a progressive federal retail sales tax on consumption. Given the aging of America's aging population, which will lead to growing health and pension costs, could adoption of the FAIR Tax Act preclude the need for higher taxes to fund these liabilities, and even lead to welfare gains?

What is the model innovation? The authors' dynamic, overlapping generations, CGE model captures detailed demographic characteristics of the U.S. economy, including age- and year-specific projections for three income classes of households within each generation (e.g., mortality rates, pension benefits, health costs). The model also includes year-specific projections of government revenue and expenditure.

What is the experiment? The authors model the Fair Tax as the replacement of most federal taxes by a progressive federal retail sales tax on consumption of 23 percent (i.e., it increases a sales price of $1 to $1.23). The plan includes a tax rebate whose size depends on households' characteristics and an increase in Social Security benefits to maintain their real purchasing power. Their tax plan reduces non-Social Security federal expenditures to help pay for the Fair Tax rebate.

What are the key findings? The Fair Tax almost doubles the U.S. capital stock by the end of the century and raise long-run real wages by 19 percent compared to the base case alternative. The winners from this reform are primarily those who are least well off, and large welfare gains accrue to future generations.

individuals' labor-leisure trade-off. A prominent example of a CGE model with both of these features was developed by Auerbach and Kotlikoff (1987) and used to analyze U.S. tax policies. A subsequent version of this model, developed by Jokisch and Kotlikoff (2005) and summarized in Text Box 8.2, was used to analyze the FAIR Act. (The FAIR Act is a plan to replace most types of U.S. taxes with a single sales tax on consumers.) Equity considerations of income taxes and income subsidies are other dimensions not typically addressed in a standard CGE model. Nevertheless, standard CGE models must still account for income taxes, even if in a rather simplified way, because they are a part of the flow of national income and spending.

However, even among standard, static CGE models, the presentation of income tax data in a SAM, and its treatment in the corresponding CGE model, may differ in meaningful ways. For this tax in particular, it is important to study your SAM in order to understand how the tax is assumed to affect

Table 8.10. *Income Tax Data in a U.S. SAM with a Regional Household ($U.S. billion)*

	Land	Labor	Capital	Income tax
Income tax	3	1,446	244	–
Regional household	31	5,397	1,632	1,693
Total factor income	34	6,844	2,921	–
Income tax rate	8.4	21.1	8.4	–

Source: GTAP v7.0 U.S. 3x3 database.

behavior in the model. Let's first consider how income tax is described in the U.S. 3x3 SAM, which includes a regional household. In the U.S. SAM, income taxes are paid directly from the column accounts of the factors of production to the income tax row account (Table 8.10). Factors pay the remaining, after-tax income directly to the regional household row account. Then, the income tax column account pays the tax revenue to the regional household row account. Therefore, all income in the economy – which is the sum of income taxes plus after-tax income – is ultimately paid to the regional household.

The income tax rate for each factor is calculated as:

$$\text{Income tax/total factor income} * 100.$$

As an example, the income tax rate for labor is:

$$1{,}446/6,844 * 100 = 21.1 \text{ percent}$$

In the U.S. SAM, the tax rate on wage income is quite high relative to the tax rates on land-based income and capital income – which are both 8.4 percent.

Recall from Chapter 3 that a regional household is a macroeconomic account similar to GDP that describes the sources of national income and the composition of aggregate demand. In a CGE model with this structure, a change in the income tax typically has no effect on the economy. To explain why, consider the income tax on labor in Table 8.10. Labor ultimately pays a total of $6.8 trillion to the regional household, composed of income taxes of $1.4 trillion plus after-tax income of $5.4 trillion. If the labor income tax rate should fall to zero, labor would still pay $6.8 trillion to the regional household, now composed entirely of after-tax income. Thus, a change in the income tax does not change regional household income or the the shares of households, government, and savings in national spending.

In some static CGE models without a regional household, an income tax has structural effects on an economy if it shifts spending power among the categories of final demand. CGE models without a regional household generally link income directly to each component of aggregate demand. For example, households spend their after-tax income and governments spend their tax revenue, so an increase in an income tax lowers household spending and increases government spending. Depending on the closure in these models, income taxes also may affect investment by changing households' after-tax savings or the government surplus or deficit (which is public savings). If households, governments, and investors differ in the type of goods that they demand, then a change in income taxes and the composition of final demand will lead to changes in the industrial structure of the economy.

Second-Best Efficiency Effects

So far, we have used a distortion-free model of the United States to study the direct and excess burdens of one type of tax at a time. In more realistic CGE models, and in real life, governments usually impose many taxes at the same time, and usually in many industries simultaneously. Policy changes therefore entail introducing or changing a tax in the presence of many preexisting tax distortions.

This tax setting raises an important question: Does the excess burden of a tax depend on the preexisting taxes in an economy? To answer this, we draw on the theory of the second best developed by the economists Richard Lipsey and Kelvin Lancaster (1956). According to this theory, a free market equilibrium in one market may not lead to the most efficient, economywide outcome if there is already a distortion in another market due to a tax, a market failure, or other type of economic constraint. For example, suppose there is already a production subsidy in the services industry that has caused its output to exceed the economically efficient level. The government now may be considering the introduction of a production subsidy to the manufacturing industry. In this distorted setting, the manufacturing subsidy could actually improve economic efficiency in the services sector by drawing away some of its productive resources. In this case, a new, distorting manufacturing subsidy may cancel out at least part of another subsidy's distortionary effect. Of course, there are circumstances where a new tax or subsidy can exacerbate the effects of existing tax distortions.

Let's explore a case of second-best in our GTAP model with the distortion-free U.S. 3x3 database. Our experiment is the introduction of a 10 percent production subsidy on U.S. manufacturing. First, we assume that there are no other distortions in the economy. The subsidy causes manufacturing output to increase by 8.57 percent, an oversupply relative to the free market level (Table 8.11). The excess burden in manufacturing of $18.5 billion corresponds to the efficiency triangles of $c + f$ in Figure 8.3b. The increased use of the economy's resources by manufacturing also causes the production of agriculture and services to decline.

Table 8.11. *Second-Best Effects of a Production Subsidy in U.S. Manufacturing With/Without a Pre-Existing Production Subsidy in U.S. Services*

	Base Production Subsidy	New Production Subsidy	% Change in Production (*qo*)	Excess Burden ($US million)
Base equilibrium with no pre-existing tax distortions				
Agriculture	0	0	−8.5	0
Manufacturing	0	10	8.6	18,521
Services	0	0	−1.6	0
Base equilibrium with a pre-existing subsidy				
Agriculture	0	0	−8.6	0
Manufacturing	0	10	8.7	18,396
Services	5	5	−1.6	−9,555

Source: GTAP model with GTAP v7.0 U.S. 3x3 database.

Now, we assume that the economy has a preexisting, 5 percent subsidy on the production of services. In this setting, there is already an oversupply of services relative to the free market level. The introduction of the manufacturing production subsidy increases manufacturing output (8.7 percent) and leads to an efficiency loss in the industry of $18.4 billion. However, in this case, manufacturing's expansion corrects for part of the inefficient oversupply of services. Its competition for the economy's productive resources causes services output to decline and yields a reduction of nearly $9.6 billion in the excess burden associated with service's production subsidy. The new distortion in the manufacturing sector therefore corrects for part of a preexisting distortion in the services sector.

Our simple example analyzes just two taxes. A CGE model with a more realistic SAM is likely to have a large number of taxes. The welfare effect of a change in any one tax is therefore the sum of its own excess burden plus its, second-best effects in correcting or exacerbating the excess burdens associated with every other tax in the model.

Marginal Welfare Burden of a Tax

The marginal welfare burden of a tax is the change in national welfare due to a very small – a marginal – change in an existing tax. The change in welfare, divided by the change in tax revenue, describes the marginal welfare burden per dollar of additional tax revenue. This per dollar concept, developed by Edgar Browning (1976), has had practical use as a yardstick for determining whether a government project is worthwhile if its funding requires raising additional tax revenue. This is a realistic and important analytical problem because policymakers are typically seeking ideas for designing modest tax hikes or tax cuts from an already-distorted tax base.

The yardstick builds on the idea that every additional dollar of tax revenue incurs both a direct tax burden, which is a transfer of tax revenue from private expenditure to the government, and an excess tax burden, which is the tax's deadweight efficiency cost to the economy. Browning studied the marginal excess burden of the U.S. labor income tax, finding that raising an additional dollar of tax revenue would generate an excess burden of nine to sixteen cents, depending on how the tax increase is structured. He concluded that the return on a government project funded by this additional tax revenue would have to be 9 to 16 percent greater than the private expenditure that it displaced, or national welfare would decline.

Browning used a partial equilibrium model for his study of the labor income tax but CGE models have proven to be well-suited for this type of analysis. One reason is that CGE models offer a comprehensive measure of the welfare effects of a change in one tax. The model takes into account not only the excess burden of the tax that changes, but also any second-best efficiency effects linked to other existing taxes. In addition, a CGE model's welfare measure includes any terms-of-trade effects due to the tax change, which may be important when the country is large in world markets.

CGE models also provide a comprehensive measure of the direct burden of a tax because they account for the impacts of a change in one tax on the revenue generated by all taxes in an economy. For example, an increase in the sales tax on cigarettes may cause employment and output in the tobacco industry to fall. Payroll and production taxes paid by the tobacco industry may then fall, and perhaps sales tax revenue from other goods will rise as consumers readjust their spending. Thus, the total change in tax revenue will likely include changes in revenue from many types of taxes in addition to the tobacco sales tax.

Ballard, Shoven, and Whalley (1985) developed a pioneering CGE-based analysis of the marginal welfare cost of the entire U.S. tax system. They found that, depending on the elasticities assumed in the model, the marginal welfare cost per dollar of additional U.S. labor income tax revenue was between twelve and twenty-three cents – substantially higher than Browning's partial equilibrium estimate. For the U.S. tax system as a whole, they calculated a marginal welfare burden of seventeen to fifty-six cents per dollar of additional tax revenue. For example, a ratio of 17 percent indicates that for a dollar of additional tax revenue, there is an additional deadweight efficiency loss to the economy of seventeen cents. In this case, a government project must yield a marginal return of at least 117 percent if it is to be worth its cost to the economy in terms of tax dollars spent plus lost efficiency. (You will replicate the Ballard, Shoven, and Whalley analysis in Model Exercise 8.) Devarajan,

Text Box 8.3. Marginal Welfare Burden of Taxes in Developing Countries
"The Marginal Cost of Public Funds in Developing Countries." (Devarajan, Thierfelder, and Suthiwart-Narueput, 2001).

What is the research question? The notion that raising a dollar of taxes could cost society more than a dollar is one of the most powerful ideas in economics. By causing agents to alter their behavior in inefficient ways as a result of the tax, the marginal cost of raising a dollar of public funds is higher than a dollar. Despite the importance of this idea, few estimates are available on the marginal welfare cost of funds in developing countries. What are the estimated costs of funds in three developing countries – Cameroon, Bangladesh, and Indonesia?

What is the CGE model innovation? A standard, static, single-country CGE model is used for each country. Their macroclosure rules fix investment, real government spending, and the current account balance. These closure rules imply that an increase in tax revenue causes a government budget surplus (i.e., public savings rise); but because investment spending is fixed, households' savings falls and their consumption rises by the full amount of the tax revenue. In effect, households are compensated in a lump-sum fashion for higher taxes so that model results measure only the excess burden of the taxes.

What is the experiment? There are four tax experiments for each country: (1) an increase in the production tax by sector; (2) a uniform increase in all production taxes, (3) an increase in individual tariff rates, and (4) a uniform tariff rate increase. Additional factor market distortions are introduced one-by-one into the Cameroon model to illustrate second-best effects.

What are the key findings? The marginal costs of funds in the three countries are quite low, ranging between 0.5 and 2.0, which refutes the conventional wisdom that the marginal costs of funds in developing countries are likely to be high due to their relatively high tax rates. Experiments in which taxes are increased by sector confirm that the marginal cost of funds is highest in sectors where distortions are large. Policies that increase the lowest tax rates tend to reduce the marginal cost of funds because the tax structure becomes more uniform.

Thierfelder, and Suthiwart-Narueput (2001) carried out a similar CGE-based analysis of the marginal costs of taxes in three developing countries, described in Text Box 8.3. Their study is of special interest because most studies of marginal welfare burdens focus on developed countries.

The concept of the marginal welfare burden is illustrated in the partial-equilibrium model shown in Figure 8.6. The figure describes changes in direct and excess burdens due to marginal increases in a production tax. In the figure, S^1 is the tax-free supply curve and, to simplify our analysis, D describes a perfectly elastic compensated demand curve. In the absence of the tax, P^1 and QO^1 are the equilibrium price and quantity. Now, assume that a specific (per unit) production tax of t^1, shown as the distance between $P^1 - P^2$,

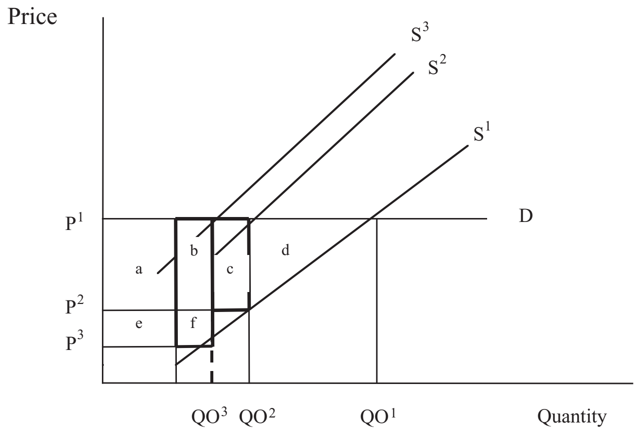

Figure 8.6. Marginal excess burden of a production tax

is already present in our initial equilibrium. The tax-inclusive supply curve corresponding to t^1 is S^2. In this tax-distorted equilibrium, consumers pay price P for quantity QO^2 and producers receive price P^2. The total loss in producer surplus is the combined area of $a + b + c + d$; but of this total, area $a + b + c$ is transferred to the government as tax revenue so it is not a loss to the economy. The excess burden of the tax is the area of triangle *d*.

Next, assume a marginal increase in the production tax to t^2, shown in the figure by the distance P^2-P^3. The increased tax raises producers' costs of production and shifts the new tax-inclusive supply curve to S^3. In the new equilibrium, consumers still pay price P^1, but producers receive only price P^3 and the equilibrium quantity declines to QO^3. Producers lose the additional producer surplus areas of $e + f$. (The small triangular area to their right can be ignored for small changes in the tax.) The government gains new tax revenue of area $e + f$ but loses tax revenue of area *c*. Area *c* becomes an addition to area *d*, the excess burden of the tax, as the tax increases from t^1 to t^2.

The marginal excess burden of the tax per dollar of additional government revenue is the ratio of the change in the excess burden to the change in tax revenue. In Figure 8.6, the ratio is described as areas $c/(e + f - c)$ for the tax increase from t^1 to t^2.

Our partial equilibrium model shown in Figure 8.6 describes only the change in excess burden in the taxed sector. Recall from our study of the theory of the second best that, in an economywide framework, a change in one tax rate may cause the excess burdens associated with other taxes in the economy to change also. In a general equilibrium model, therefore, measurement of the marginal welfare effect will include the marginal excess burden associated with all taxes in the economy, as well as any changes in

Table 8.12. *Marginal Welfare Effect of a 1 Percent Increase in The U.S. Production Tax on Services*

Excess Burden by Tax	
Total excess burden	−18.9
Import tax	−10.6
Export tax	2.5
Production tax	−15.3
Sales tax on intermediate inputs	−7.7
Sales tax on final demand	16.3
Factor use tax	−4.1
Terms of trade	−140.3
Total welfare effect	−159.2

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

the terms of trade. Changes in tax revenue, too, are the sum of changes in revenue from all tax sources.

To illustrate these points, we use the GTAP model with the distorted U.S. 3x3 database to analyze the welfare effect of a marginal, 1 percent increase in the initial 2.8 percent tax on U.S production of services. Our model results indicate that the increase in the tax on services increases the total excess burden, or efficiency loss, by \$18.9 million and causes welfare to decline by \$159.2 million (Table 8.12). The efficiency losses are associated with production, import, and factor use taxes, whereas other types of taxes generate second-best efficiency gains. Total U.S. tax revenue increases by \$3.492 billion. Thus, the marginal welfare burden of the additional tax revenue is:

$$\text{Change in welfare/Change in tax revenue} * 100$$
$$-159/3,492 * 100 = -4.6 \text{ percent.}$$

This means that an additional tax dollar costs 4.6 cents in efficiency losses. The government project should be undertaken only if its marginal benefit will be at least 4.6 percent greater than the amount of the additional producer tax revenue required to finance it. Otherwise, its cost to the economy in terms of tax dollars spent plus related efficiency losses will be greater than its benefit.

In an already distorted economy, it is also possible that the tax increase could lead to marginal welfare gains. In this case, the ratio is positive. If, for example, the ratio is 10 percent, then a public project could generate a marginal benefit that is as little as 90 percent of its cost in taxpayer funding and still be worthwhile because the tax increase corrects other distortions in the economy. This scenario may not be too far-fetched; our model results in table 8.12 showed that a marginal increase in a U.S. production tax yielded second-best welfare gains associated with some pre-existing U.S. taxes.

Summary

Our study of tax policy analysis in a CGE model began with an examination of the tax data in the SAM, because the SAM describes the agent who pays the tax, the production or consumption decision on which the tax is assumed to be levied and tax revenues. We studied five types of taxes: trade taxes on exports and imports, and taxes on production, sales, factor use, and incomes. Our study of each tax began with a simple, partial equilibrium, theoretical model that illustrated how taxes distort production and consumption decisions and result in a direct burden (the tax revenue that it generates) and an excess burden (the loss in production and consumption inefficiency). Our theoretical approaches helped us to formulate expectations about the effects of taxes on the economy under study, identify key results, and recognize the consistency of CGE model results with theoretical models of taxation. We then progressed from analyzing single taxes in partial equilibrium frameworks to analyzing taxes in general equilibrium, culminating in applied examples of second-best effects and the marginal burden of a tax system.

Key Terms

Ad valorem tariff or tax
Direct burden
Direct tax
Excess burden
Export tax
Factor use tax
Import tariff
Income tax
Indirect tax
Marginal welfare burden
Output tax
Tax incidence
Sales tax
Second-best effects
Specific tariff or tax

PRACTICE AND REVIEW

1. Suppose the government is considering the introduction of an import tariff on one of two products – one product exhibits a high own-price elasticity of demand

and the other has a low elasticity. In a graph, compare the effects of a tariff on the excess burden for the two goods. Label the axes, curves, and initial market equilibrium. On which type of good do you recommend that the tariff be imposed? Explain why.

2. Use data from the U.S. 3x3 SAM to calculate the factor use tax (or subsidy) rate for labor and capital used in the production of manufactures and of services. How do these factor use taxes distort the allocation of capital and labor between the manufacturing and service sectors? How do they distort the ratios of labor to capital within each industry?
3. Assume that a country introduces a 25 percent sales tax on the purchase of gasoline. Draw a graph of the effects of the sales tax on the supply and demand for gas. Label the axes and curves, and explain your assumptions about the elasticities of supply and demand that define the slopes of your curves. Identify the direct tax burden, the excess burden, and changes in the market equilibrium price and quantity.
4. Suppose that the government increases retail sales taxes on students' purchases of selected items in the university bookstore. Government analysts project a $1 million increase in sales tax revenue that will fund a reduction in student tuition, and a marginal welfare loss of $200,000.
   a. What is the marginal welfare cost of the tax increase, per dollar of additional tax revenue?
   b. What is the minimum return that the government must make on its investment in the university to ensure that national welfare does not decline?
   c. How do you think the marginal welfare cost per dollar might change if the government increases the sales tax on a good for which student demand is relatively price inelastic, such as food? What if the government increases the sales tax on a good for which demand is relatively price sensitive, such as novelty items with the school logo?
   d. Assume a preexisting production subsidy in the industry that supplies the university bookstore with taxed items, such as textbooks. In a short paragraph, explain the possible second-best effect of the new tax.

Technical Appendix 8.1: Compensated Demand and Welfare Effects

In this chapter, we mostly use partial equilibrium models to illustrate the effect of a tax on the supply and demand for a single good. Similar to our study in Chapter 4 of consumer demand for two goods, we can decompose the consumer's response to a tax-induced price change for one good into income and substitution effects. If the good is normal, which is the case in standard CGE models, the income effect on demand for a good is always positive (negative) when its price declines (increases). The substitution effect describes the change in consumer demand for a good when its price changes, holding purchasing power constant. In CGE models, the substitution effect is always positive (negative) when the price of a good declines (increases).

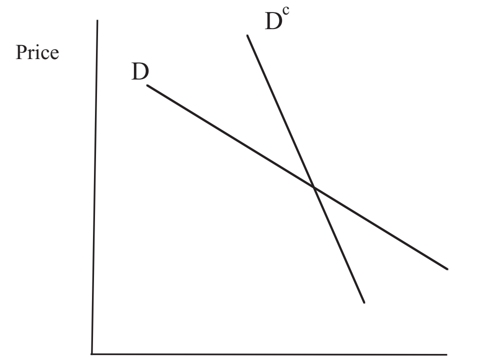

Figure 8.7. Compensated and uncompensated demand curves

To measure the welfare effects of a tax, we want to be able to describe only its substitution effect (its excess burden), since the income effect is a transfer of purchasing power from the consumer to the government and is not a loss to the economy as whole.

Economists use compensated demand curves to describe the substitution effects of a price change, exclusive of income effects. These curves describe the consumer's budget allocation, assuming that he is fully compensated for the effect of the tax on his purchasing power. In Figure 8.7, we plot both an uncompensated demand curve, D, and a compensated demand curve, D^c. The uncompensated curve is a usual (Marshallian) demand curve that includes both the income and substitution effects of a price change. The compensated (Hicksian) demand curve describes only the substitution effect. The two curves intersect at the initial market equilibrium. When the price increases, the consumer is given additional income to compensate for the loss in purchasing power, so compensated demand exceeds uncompensated demand, and vice versa. Notice, too, that the compensated curve is relatively inelastic. The consumer response is smaller because this measure includes only the price effect.

Figure 8.8 illustrates the welfare effect of a tax that increases the price of a good from P^1 to P^2. In the figure, D is the uncompensated demand curve and D^{c1} is the initial compensated demand curve. Both demand curves pass through Point A, depicting the initial equilibrium quantity, Q^1, and price P^1. An increase in price due to a sales tax causes the consumer to move upward along the uncompensated demand curve, and the quantity demanded declines to Q^2 at price P^2, at point B. We draw a second compensated demand curve, D^{c2}, consistent with this new, lower level of purchasing power. Both D and D^{c2} pass through point B.

The welfare effect of the tax is the loss in consumer surplus associated with the compensated demand curves. The figure illustrates that, because there

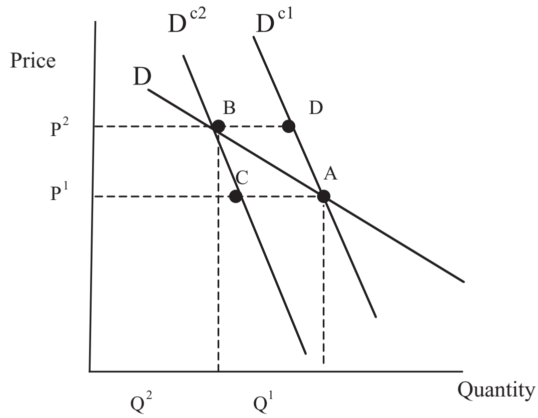

Figure 8.8. Equivalent and compensated variation welfare effects

are two compensated demand curves associated with the pre- and post-shock equilibria. We can measure the welfare effect in two alternative ways. One approach is to assume that the consumer remains on the initial compensated demand curve, as we do in our partial equilibrium diagrams in Chapter 8. In this case, the loss in consumer surplus is described by area P^2DAP^1. This area is the compensated variation measure of welfare; it quantifies the minimum amount that consumers would be willing accept as compensation to leave them as well off as before the price increase. The alternative is to measure the change in surplus based on the new level of utility associated with D^{c2}, which is described by area P^2BCP^1. This is the equivalent variation measure of welfare. It is equivalent to the maximum amount of income consumers would be willing to pay to return to the old price level. Our modeling examples in Chapter 8 report the equivalent variation measure of the welfare effects of various taxes.