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Trade in a CGE Model

In this chapter, we present the building blocks for trade policy analysis using a computable general equilibrium (CGE) model. We begin by reviewing the trade data in the Social Accounting Matrix (SAM). Next, we introduce two concepts, the real exchange rate and terms of trade, and explain how they are represented in standard CGE models. We then focus on trade theory as we simulate and interpret the results of two types of shocks: A change in endowment that changes comparative advantage, and a change in world prices that changes industry structure, trade and factor returns. We study an example of "Dutch Disease," a problem that illustrates the links between a change in world prices, the real exchange rate, and industry structure. We conclude with an explanation of the role of trade and transport costs in international trade.

Since David Ricardo first developed the theory of comparative advantage, showing that nations gain from specializing in the goods that they produce at relatively lower cost, most students of economics have learned that all countries can gain from trade. Yet, many countries are reluctant to move too far or too fast toward free trade. Their reasoning is not inconsistent with Ricardo's theory. Trade and specialization lead to changes in a country's industry's structure and, in turn, to changes in the wages and rents of factors used in production. Therefore, although trade confers broad benefits on a country, it can also create winners and losers. Protecting, compensating, or managing the social and economic transition of those who lose, has led many countries to qualify or delay their commitment to global free trade.

Since the early 1990s, CGE models have been widely used to analyze trade policy issues including unilateral trade liberalization, multilateral tariff reforms through the World Trade Organization (WTO), and regional free trade agreements such as the North American Free Trade Agreement (NAFTA) and the European Union's expansion. The contributions made by CGE models rest on their ability to identify which industries will grow or could contract with freer trade, to quantify the effects on economywide employment and factor returns, and, perhaps most important, to measure

Table 7.1. *Import Data in the SAM ($U.S. billions)*

	Commodity–Import Variety			
	Agriculture	Manufacturing	Services	Total
Tax–imports	1	24	0	25
Trade margin–imports	9	47	0	56
Rest-of-world	167	1,203	230	1,601
Total	177	1,274	230	1,682

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

welfare effects, which summarize the overall effects of changing trade policies on an economy's well-being.

In this chapter, we present the building blocks for trade policy analysis using a CGE model. Our objective is to show, through discussion and example, how to use trade theory to understand and interpret the economic behavior observed in a CGE model. We begin by reviewing the trade data in the SAM, which separately reports exports, imports, tariffs and export taxes, and trade margins. Next, we define two concepts, the real exchange rate and terms of trade, and demonstrate how they behave in standard CGE models. We build on these two concepts as we study two types of shocks: a change in factor endowments that changes a country's production and terms of trade, and a change in world prices that affects production and factor returns. We also study the trade and transportation costs incurred in shipping goods from the exporter to the importer, and learn how changes in these costs can influence world trade flows.

Trade Data in a SAM

Import data are reported in the SAM as an expenditure by the import variety of each commodity column account. The import data separately report spending on import tariffs, trade margin costs, and the cost of the imports (valued in foreign *fob* export prices). For example, the United States spends a total of $177 billion on imported agricultural goods (Table 7.1). Of this amount, $1 billion is spent on import tariffs, $9 billion is spent on the trade and transport margins that brought the goods from foreign ports to the United States, and $167 billion is the amount paid to agricultural exporters in the rest of the world. The United States spends a total of $1,682 on imports, of which $1,601 is paid to exporters and the remainder is spent on U.S. import tariffs and trade margin costs.

The SAM decomposes export data into spending on export taxes, the value of exported trade margin services, and the value of all other types of exported goods and services. (Table 7.2). The SAM's domestic commodity

Table 7.2. *Export Data in the SAM $U.S. billions)*

Commodity–Domestic Variety	Mfg. Commodity Domestic Variety	Trade Margin–Export	Rest-of-World
Agriculture	0	0	50
Manufacturing	0	0	756
Services	0	24	259
Savings–investment	0	32	536
Export taxes	2	0	0
Total	–	56	1,601

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

column accounts pay export taxes. In the United States, only manufacturing pays export taxes, which total $2 billion. The column account for export trade margins reports the export of U.S. services to the global trade and transport industry ($24 billion). The rest-of-world column account reports foreign purchases of U.S.-produced goods and services. These total $1,065 billion ($50 + $756 + $259 billion), valued in U.S. *fob* world export prices.

The balance of trade in trade margins is a deficit of $32 billion (the difference between $56 billion spent on import margins and $24 billion of exported margin services). The trade balance in goods and services, also a deficit, is the value of exports minus the value of imports, valued in world *fob* prices: $1,065 − $1,601 = −$536 billion. Both deficits are reported as positive payments by the trade margin and rest-of-world accounts to the savings-investment row of the SAM because these are inflows of foreign savings to the United States. The total U.S. trade deficit is the sum of the two trade deficits: $568 billion.

Exchange Rates

CGE models differ in their treatment of the exchange rate. Some have a ***nominal exchange rate*** variable that describes the rate at which currencies can be exchanged for one another. Usually, it is expressed as units of domestic currency per unit of foreign currency. For example, the exchange rate (EXR) of the U.S. dollar (the domestic currency) relative to the euro (the foreign currency) is defined as the number of dollars that can be exchanged for one euro:

$$\text{EXR} = \$/\text{euro}.$$

When this type of CGE model includes country SAMs that are denominated in different currencies, the initial value of the exchange rate is the market rate that prevailed in the year corresponding to the SAM database. For example, the U.S. exchange rate would be 1.30 in a CGE model of the U.S. and the European Union with a 2010 database. More often, all SAMs in a CGE model are denominated in dollars, or the CGE model has a single country. In these cases, the modeler defines the initial value of the exchange rate as one. Model results then report the percent change in the nominal exchange rate relative to the base period.

A rise in a country's exchange rate signals home currency depreciation because more domestic currency is required in exchange for the same quantity of foreign currency. For example, a rise in the exchange rate from $1.00/euro to $1.30/euro means that the U.S. dollar has depreciated relative to the euro. Conversely, a fall in the exchange rate signals home currency appreciation.

This nominal exchange rate may seem like a financial variable, but remember that a standard, real CGE model does not account for financial assets or describe financial markets. Instead, the nominal exchange rate is a model variable that determines the ***real exchange rate***, which is the relative price of traded to non-traded goods.[1] Traded goods are products that are imported or exported. Non-traded goods are products that are produced by, and sold to, the domestic market.

Let's first consider the import side. Recall from our discussion of import demand in Chapter 4 that consumers buy a composite commodity, such as autos, composed of the imported and domestically produced (nontraded) varieties. A change in the nominal exchange rate variable, EXR, affects the consumer's import price, PM, of good *i*:

$$\mathrm{PM}_{\mathrm{i}} = \mathrm{EXR} * \mathrm{PXW}_{i}$$

where PXW is the global price. For clarity, we assume there are no import taxes. Since the price of the domestically produced variety, PD, does not change, a change in the exchange rate will change the price ratio PD/PM. Let's assume that EXR rises (i.e., a depreciation), then, depending on the size of the Armington import substitution elasticity, the quantity ratio of the imported to the nontraded varieties in the consumption bundle will fall.

As an example, assume that Mexico is a small country in the world market for its auto imports, facing a fixed world import price that is denominated in U.S. dollars or a basket of foreign currencies. Assume, too, that the Mexican peso depreciates. Mexican consumers now must pay more in pesos for the same number of imported autos. As imports become relatively expensive, Mexican demand will shift toward domestic models, subject to consumer preferences as described by the import substitution elasticity. Conversely, if the peso appreciates, then the cost of imported autos in terms of pesos will fall and consumption will shift toward imports.

[1] See Robinson (2006) for a more detailed discussion of the role of a nominal exchange rate variable in a standard CGE model.

Table 7.3. *Causes and Effects of a Change in the Nominal Exchange Rate Variable on Traded Quantities When the Current Account Balance is Fixed*

Cause	Change in Nominal Exchange Rate Variable	Effect on Opposite Trade Flow
Imports rise	Depreciation	Exports rise
Imports fall	Appreciation	Exports fall
Exports rise	Appreciation	Imports rise
Exports fall	Depreciation	Imports fall

Likewise, recall from our discussion of export supply in chapter 5 that some CGE models describe producers' decisions to allocate production between domestic and export sales. A change in the nominal exchange rate variable will change the *fob* export price of good *i*:

$$PE_i = EXR * PXW_i$$

For clarity, we assume there are no export taxes. For example, a rise in the nominal exchange rate variable will decrease the price ratio PD/PE. Depending on the size of the export transformation elasticity, the share of nontraded to exported varieties in the production mix will increase.

Let's assume that Mexico is small in the world market for its exports, too, and faces fixed world export prices that are denominated in foreign currency. A depreciation of the peso will therefore generate more pesos for any given quantity of exports. Mexican producers will shift their sales toward the export market, subject to technological feasibility. Conversely, exchange rate appreciation would cause a fall in peso earnings from any given quantity of exports, so producers will shift their sales toward the domestic market.

The nominal exchange rate variable may be either flexible or fixed in value, depending on the model is macro closure. In practice, modelers often assume a closure in which a flexible exchange rate variable adjusts to maintain a fixed current account balance. The current account balance is the trade balance (the *fob* value of exports minus imports) plus other international monetary flows. One reason that modelers choose this closure is because changes in the current account balance are determined in part by macroeconomic and financial forces that lie outside the scope of real CGE models. It is therefore straightforward and transparent simply to fix the current account balance at the level observed in the initial equilibrium. A second reason is that most countries today have floating exchange rates; however, this is not always the case, and this closure decision offers the modeler the ability to explore alternative exchange rate regimes.

Table 7.3 describes how a flexible exchange rate variable adjusts to equilibrate a fixed current account balance. Suppose, for example, that a country's imports increase, perhaps because the country has removed its import tariffs. Its current account balance will worsen as the value of imports grows relative to exports. The exchange rate variable will therefore depreciate, both causing export quantities to rise and dampening the increase in import quantities, until the initial current account balance is restored.

The nominal exchange rate is a macroeconomic variable because it affects the relative prices of all traded and nontraded goods by the same proportion. For example, an exchange rate depreciation of 10 percent would increase the import price of steel, autos, books, and all other imported goods by 10 percent relative to domestically-produced steel, autos, books, etc. (and assuming a fixed world price.)

Some CGE models do not have an explicit, nominal exchange rate, but they nevertheless describe a real exchange rate mechanism. In the GTAP model, for example, a change in relative factor prices across countries, variable *pfactor*, reflects changes in the relative prices of goods that are similar in effect to a change in the real exchange rate. The *pfactor* variable describes the percent change in an index of a country's factor prices relative to the world average factor price, which is the model numeraire. An increase (decrease) in the variable is similar to a real exchange rate appreciation (depreciation). For example, consider two countries (A and B) that both produce apparel. A shock that lowers economy-wide wages in country A causes its world export price of apparel to fall relative to the world export price of apparel from the higher-wage, country B. Indeed, all goods produced in country A using labor become cheaper in the world market than similar goods from country B. This will stimulate A's consumers to shift from imports toward domestic goods in their consumption, and will lead country B's consumers to shift toward imports from domestic goods. Thus, a change in this factor price exchange rate leads to adjustments that are similar to those of a nominal exchange rate depreciation by A.

Terms of Trade

Terms of trade measure the import purchasing power of a country's exports. Any change in the terms of trade therefore affects an economy's well-being, or welfare, by changing its consumption possibilities. Terms of trade are calculated as the ratio of the price of a country's export good to the price of its import good. Prices are compared in *fob* prices, exclusive of trade margins, otherwise, a change in shipping costs would appear to change the relative prices of the two goods. Import tariffs are also excluded.

As an example, consider a two-country, two-good world in which the home country (country A) exports corn to its trade partner (country B), and B exports oil to A. Country A's terms of trade is the ratio of A's *fob* export

Table 7.4. *A Two-country Example of Terms of Trade Changes*

	% Change from Base			
	A's *fob* World Export Price of Corn	B's *fob* World Export Price of Oil	A's Terms of Trade	B's Terms of Trade
Scenario 1	25	−10	35	−35
Scenario 2	−2	8	−10	10

price of corn to B's *fob* export price of oil, and vice versa. A terms-of-trade improvement for A means that the price for its corn export has increased relative to the price of its oil import. The corn price may have increased or the oil price may have fallen, or both may have changed, as long as the corn price rose relative to the oil price. A's terms-of-trade improvement means that the export earnings from each unit of its corn exports now has more import-purchasing power for oil imports.

Table 7.4 presents two numerical examples to illustrate this concept. Because the price data are reported in percentage change terms, the percentage change in a country's export price minus the percentage change in its import price measures the percentage change in its terms of trade. In scenario 1, country A experiences a terms-of-trade gain, because its export price rises relative to B's export price; but A experiences a terms-of-trade loss in scenario 2. Notice, too, that A's terms-of-trade gain is exactly equal to country B's terms-of-trade loss, so globally, the terms of trade changes sum to zero.

Countries usually export and import many types of goods with many trade partners. A global CGE model that tracks bilateral trade flows and includes the Armington assumption that goods are differentiated by origin, has as many bilateral export prices as there are countries and commodities in the model. In this case, a country's terms of trade can be calculated as a price index that is defined for either an industry or for total imports and exports. Either index is calculated as a trade-weighted sum of the home country's bilateral (*fob*) export prices relative to a trade-weighted sum of the *fob* prices of its imports. The trade weights on the export side are the quantity shares of each trade partner in the home country's export market. The weights on the import side are the quantity shares of each source country in the home country's imports.[2] Terms-of-trade changes can vary widely among countries even though, globally, the terms-of-trade changes for all countries sum to zero.

A "small" country does not experience terms-of-trade effects because its world market shares are too small for changes in its export and import quantities to affect global prices. Single-country CGE models often, but not necessarily, include the assumption that a country is small in world markets and

[2] See Chapter 2 for an example of how to calculate a trade-weighted price index.

that its world export and import prices are fixed. However, in multicountry CGE models with Armington import aggregation functions, every country is potentially "large" to some extent – even countries that we ordinarily think of as small. Therefore, all countries in a multicountry model can experience terms-of-trade changes.

An important, practical implication of the use of Armington functions in multicountry CGE models is that terms-of-trade effects are usually due to larger changes in countries' world export prices than in their import prices. This insight was developed by Brown (1987), who studied terms-of-trade effects in the multicountry Michigan Model of international trade. To understand why this is so, consider what might happen if a very small country like Israel imposes a tariff on its orange imports, causing its consumers to reduce their import quantity and consume more domestically produced oranges. Israel's bilateral world import prices for oranges will likely fall, but not by much, since Israel is only one of many customers in each of its suppliers' markets, and probably only a small one at that. However, even a small country like Israel is large in its export market because the Armington assumption, that products are differentiated by source country, implies that Israel is the monopoly supplier of Israeli oranges. Increased domestic demand reduces the supply of Israeli oranges available for export. When the quantity of Israeli orange exports declines, its world export price will rise, perhaps by a lot if its foreign customers are unwilling to substitute their domestic good for the Israeli variety. (i.e., they have a low Armington import substitution elasticity)

We explore these concepts 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. manufacturing import tariff from 1.9 percent to 15 percent. We compare the terms-of-trade results for the United States' manufacturing sector when import substitution elasticities in manufacturing for all countries are assumed to have a relatively low value of three versus a high value of ten.[3]

Experiment results related to imports show that the tariff increases the price paid by U.S. consumers for manufactured imports from the rest-of-world, and causes the U.S. import demand quantity to fall (Table 7.5). The higher the import substitution elasticity, the greater is the fall in the U.S. import quantity. The United States is a large enough customer that a decline in its import demand causes the rest-of-world's bilateral export price to fall, which contributes to a terms-of-trade gain on the U.S. import side.

[3] Note that the GTAP model includes a third stage in the consumer decision that, for a given quantity of imports, describes the sourcing of imports from among suppliers. We define identical import substitution elasticities for both levels of the model's import aggregation functions: import versus domestic, and import sourcing.

Table 7.5. *Terms of Trade Effects on U.S. Manufacturing from a 15% U.S. Tariff on Manufactured Imports (% change from base values)*

Import Substitution Elasticities	Mfg. Import Quantity (*qiw*)	Mfg. Export Quantity (*qxw*)	Bilateral ROW Mfg. Export Price to United States ($pfob_{ROW}$)	Bilateral U.S. Mfg. Export Price to ROW ($pfob_{US}$)	U.S. Terms of. Trade in Mfg. ($pfob_{US}$)− ($pfob_{FOW}$)
3	−20.82	−26.11	−0.83	3.32	4.15
10	−45.91	−46.65	−1.71	5.02	6.73

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

On the export side, the shift in U.S. demand toward consumption of the domestic variety causes the quantity of U.S. manufacturing available for export to fall. The higher the U.S. import substitution elasticity, the larger the decline in the U.S. export quantity. The decreased availability of U.S. exports drives up the world price of U.S. manufacturing exports and leads to a U.S. terms-of-trade gain that becomes larger as the import substitution elasticities become larger.[4] On net, most of the U.S. terms-of-trade gain is attributable to an increase in the U.S. export price.

Terms-of-trade effects can be an important outcome of any type of shock to an open economy. Many CGE analyses of trade liberalization find that the terms-of-trade effects are quite large and can even dominate efficiency gains in determining the welfare effects of trade policy reform. However, even when the modeler makes the small-country assumption and fixes the terms of trade, this variable remains a relevant subject of CGE analysis because exogenous changes in the world import or export price can be introduced as an experiment. As an example, the modeler could explore the effects of an increase in the world price of a natural resource export on a small, resource-exporting country, as we do later in this chapter in our discussion of Dutch Disease.

Trade Theory in CGE Models

Economists Eli Heckscher and Bertil Ohlin developed a simple, two-good, two-factor, and two-country model to explain the relationship between countries' relative factor endowments and the composition of their trade. In their

[4] In the GTAP model, the import substitution elasticities may differ by commodity but are identical for all countries. Increasing the import demand elasticity for the U.S. contributes to a larger U.S. terms of trade gain in its export price; but the simultaneous increase in the ROW import demand elasticity also tends to reduce that terms of trade gain. A higher elasticity value makes foreign consumers more willing to substitute away from the U.S. product as the U.S. export price rises. See Brown (1987) for a discussion of terms of trade effects in the case where import demand elasticities for the same commodity differ by trade partner.

stylized model, the two countries differ only in their relative factor endowments – one has a larger endowment of labor relative to capital, and the other has a larger endowment of capital relative to labor. The ***Heckscher-Ohlin theorem*** posits that both countries will export goods that are intensive in the factors of production that are in relatively abundant supply, and import goods that are intensive in the factors of production that are in relatively scarce supply.

This powerful insight into why countries trade has yielded additional theorems about trade. Two theorems that derive from the Heckscher-Ohlin model describe the effects of changes in factor endowments on industry structure (the ***Rybczynski theorem***) and the terms-of-trade; and the effects of changes in world prices on factor returns and income distribution (the ***Stolper-Samuelson theorem***). Because both theorems focus attention on the effects of changing market conditions on economic structure and factor income, they are of special interest to CGE modelers because these are the outcomes that we largely focus on in our studies.

However, the two theorems rest on very specific assumptions that are not usually met in the more realistic, applied CGE models that we are studying. For example, in our U.S. 3x3 model, the two regions both export and import the same type of good, and their production technologies differ. In many applied CGE models, there are more factors, more industries, and (in multicountry models) more countries than in the stylized theoretical models that yield these theorems. Nevertheless, grounding our interpretation of CGE model results in these theorems remains useful. In the following sections, we show how the theorems help us to identify which model results are most relevant to consider, and how they provide us with insights that help us understand and explain our results. Results tend to be consistent with, although they do not necessarily follow directly from, the stylized models of international trade.

Factor Endowment Changes, Trade, and Terms of Trade

A country's factor endowments can change for many reasons. Over the long term, economies grow because of the gradual accumulation of factor supplies, as savings augment the capital stock and population growth increases the labor supply. Economic shocks also affect factor supplies, such as labor immigration, capital inflows, and war and disease. And, as we learned in Chapter 6, a change in productivity changes the effective endowment of a factor. Education and training, for example, increase the effective number of workers, even if the actual number of workers remains the same.

A change in factor endowments can change a country's comparative advantage and lead to changes in the types of goods that it produces and trades.

Table 7.6. *Endowment Growth and Rybczynski Effects*

Endowment Growth	Exportable Output	Importable Output	Terms of Trade
Factor used intensively in exportable	+	−	−
Factor used intensively in importable	−	+	+

In turn, changes in a country's export supply and import demand can lead to changes in its terms of trade. These ideas were developed formally by the economist Tadeusz Rybczynski (1955). He posited that a change in the endowment of one factor has two effects. First, an increase in the quantity of one factor leads to an absolute increase in the production of the good that uses that factor intensively, and an absolute decrease in production of the good that does not use it intensively, holding world prices constant (Table 7.6). This observation is known as the Rybczynski theorem. Second, if the country engages in trade and if the quantity of the endowment used intensively in its export good increases, then its export supply and import demand will increase, and its terms of trade will deteriorate. On the other hand, if the endowment used intensively in the importable good increases, then the country's imports and exports will decline, and its terms of trade will improve.

Figure 7.1 illustrates the producer's efficiency-maximizing behavior that drives the Rybczynski theorem. First, assume that there are two sectors in the economy; one that produces exportable goods and one that produces importable goods. We also assume that the exportable sector is labor intensive and the importable sector is capital intensive. The figure includes a product transformation curve, QO^1, drawn concave to the origin. It represents all possible combinations of outputs of the exportable, QE, and importable, QE, goods that can be produced with a given factor endowment. Recall from Chapter 5 that the slope of any point on a transformation curve describes the marginal rate of transformation (MRT), which is equal to the ratios of the marginal costs of the importable to the exportable: MC_M/MC_E. As the producer moves down the transformation curve and relatively more of the importable good is produced, the prices of the importable's inputs are bid up, and the ratio MC_M/MC_E increases. The lines in the figure define the relative global prices of the country's export (PXW_E) and its import (PXW_M). For now, we assume that world prices are fixed, and the country is small in world markets, so both price lines have the same slope $-PXW_M/PXW_E$. In the initial equilibrium, output is at quantity ratio QM^1/QE^1. At this tangency, the ratios $MC_M/MC_E = PXW_M/PXW_E$. Rearranging, $MC_M/PXW_M{}^1 = MC_E/PXW_E{}^1$. This means that the producer optimizes when the marginal cost per dollar earned from the sale of both goods are equal.

Text Box 7.1. Rybczynski Effects in a Global CGE Model of East Asia
"Historical Analysis of Growth and Trade Patterns in the Pacific Rim: An Evaluation of the GTAP Framework." (Gehlhar, 1997).

What is the research question? A CGE model's validity is often tested by scrutinizing assumptions about behavioral equations and their elasticity parameters. This analysis proposes a more rigorous test by asking whether the GTAP model is capable of explaining and reproducing historical trade flows.

What is the CGE model innovation? The author performs an exercise in "backcasting" (as opposed to "forecasting") by seeing whether the GTAP model can replicate historical, bilateral trade flows. Because the GTAP model is based on standard, neoclassical theory, the author chooses a backcasting exercise that the theory is capable of explaining – the link between factor endowments and the commodity composition of trade. In general, East Asian countries are observed to have had faster growth in their human and physical capital stocks over 1982–92 than developed countries and the composition of their exports has consequently shifted from labor intensive to skill and capital intensive products. The author uses the CGE model to reverse East Asia's factor endowment growth and observe model results for Rybczynski-type effects on industry structure and trade.

What is the experiment? For each country/region, four types of endowments are reduced from their 1992 levels to 1982 levels: population, labor force, human capital, and physical capital. The same experiment is carried out with (1) the default import substitution elasticities; (2) a 20 percent increase in all import elasticities; (3) a database that disaggregates the labor force into skilled and unskilled workers and (4) a combination of the human capital split and higher import substitution elasticity parameters.

What are the key findings? There is a strong correlation between countries' actual 1982 shares in world trade by commodities and the trade shares simulated by the model. The correlation is strongest when trade elasticities are relatively large and labor is divided into skilled and unskilled workers. The comparison of correlations across the four scenarios demonstrates that elasticities and labor market disaggregation by skill level are critical assumptions in terms of the model's predictive ability.

In the figure, the convex curves are consumer indifference curves that describe all possible combinations of the exportable and importable good that yield equal utility to domestic consumers. Notice that the country's utility-maximizing consumption basket is different from its optimal production mix. In this country, international trade gives consumers the opportunity to consume a larger ratio of importable to exportable goods than it produces.

An increase in the country's labor endowment shifts its export transformation curve outward to QO^2 because now more of both goods can be produced. The increase in the labor supply drives down wages, which is most cost saving

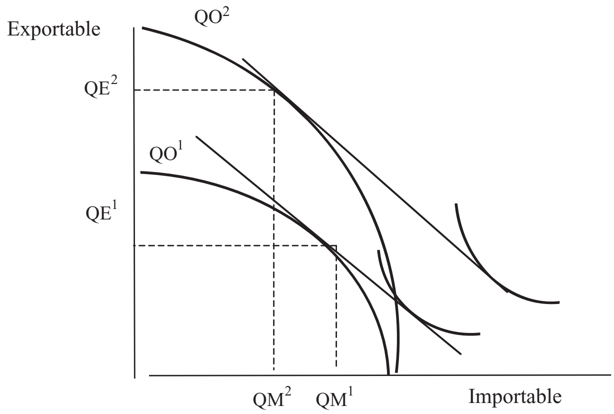

Figure 7.1. Exportable-expanding factor growth

for the exportable sector, which is relatively labor intensive. That is why the curve shifts out further on the exportable axis than on the importable axis. The fall in the wage causes MC_E to fall relative to MC_M at the initial product ratio of $Q_M{}^1$ and $Q_E{}^1$. Producers adjust by shifting toward production of the labor-intensive exportable, which drives wages back up until the marginal cost per dollar earned from exportables is again equal to that from importable production. At given world prices, the optimal production mix is now QE^2 and QM^2.

The increase in supply of exportables leads to an increase in export supply, and the decline in importable production leads to higher import demand. If we now assume that the country is large enough in world markets to affect world prices, then the world price of its exportable will fall, and the world price of its importable will rise. That is, the country's terms of trade will decline.

The effect of an increase in the capital stock, used intensively in the importable good, is analyzed in a similar fashion. In this case, production of the importable increases and import demand falls. Production of the exportable falls and export supply falls. The changes in the country's trade will lead to an improvement in its terms of trade.

This is the theoretical context for understanding the trade, and terms-of-trade, effects of CGE model experiments that increase the endowment of one factor. However, before we can explore Rybczynski effects in our CGE model, we first need to examine the U.S. 3x3 data to compare factor intensities across sectors and to identify which sectors are exportable or importable.

Based on data from the U.S. structure table (Table 3.4) on labor and capital shares in factor costs, we know that agriculture is the most capital intensive U.S. sector, and that manufacturing and services are equally labor intensive. Commodities are more exportable as the export share in production increases, and more importable as the import share of consumption increases. According to data from the U.S. structure table, manufacturing is a relatively exportable product compared to agriculture, and agriculture is relatively importable compared to manufacturing. Services are close to being a nontraded good, a possibility not considered in Rybczynski's stylized two-sector model and another example of how our applied model diverges from the strict assumptions of theory.

With this grounding in theory and in our model data, we can use the GTAP model with the U.S. 3x3 database to analyze a change in a factor endowment used intensively in the exportable sector. Our experiment is a 10-percent increase in the U.S. labor supply. The shock causes U.S. wages to fall by 1.62 percent, and capital rents to rise by 0.79 percent. On net, the U.S. experiences a real depreciation because its factor price index falls 0.91 percent relative to those in the rest of the world. Other results, reported in Table 7.7, are consistent with the Rybczynski effects. Production increases by more in the exportable sector (manufactures) than in the importable sector (agriculture) although output in both sectors increases because growth in the U.S. labor supply increases the productive capacity of its economy. Exports increase by more in the exportable than in the importable sector, but exports by both sectors increase. Imports increase by more in the importable than in the exportable sector, but imports increase in both.

Price results, too, are consistent with Rybczynski effects. The U.S. world export price declines most in the exportable sector and its import price increases most in agriculture. The Rybczynski prediction that the overall terms of trade will decline is also supported by our model.

World Price Changes and Factor Income Distribution

What happens to a country's wages and capital rents when world prices change? The Stolper-Samuelson theorem predicts that in a two-good economy, a change in the relative prices of goods will lead to a change in relative factor prices and the distribution of national income. The price of the factor used intensively in the production of the good whose relative price has risen will increase. The price of the factor used intensively in the production of the good whose relative price has decreased will fall.

The reasoning is as follows: An increase in the world price of one good will cause an economy's production to shift toward increased production of that good and away from production of the other good. If each industry employs a different mix of factors, then the composition of the economywide demand for factors will shift, leading to a change in relative factor prices.

Table 7.7. *Effects of a 10 Percent Increase in the U.S. Labor Supply (% change from base values)*

	Base Data: Initial Labor Share in Factor Costs	Output (qo)	Exports (qxw)	Imports (qiw)	World Price of U.S.: Export ($pfob_{US}$)	World Price of U.S.: Imports ($pfob_{ROW}$)	World Price of U.S.: Terms of Trade ($pfob_{us} - pfob_{row}$)
Agriculture	.32	7.18	5.73	5.51	−.26	.39	−.65
Manufacturing	.73	7.32	6.82	3.57	−.70	.35	−1.05
Services	.73	7.06	4.38	4.71	−.90	.38	−1.28

Note: Elasticity of factor substitution is four in all sectors.
Source: GTAP model, U.S. GTAP v.7.0 3x3 database.

Text Box 7.2. Stolper-Samuelson vs. Migration Effects in NAFTA
"Wage Changes in a U.S.-Mexico Free Trade Area: Migration versus Stolper-Samuelson Effects." Burfisher, Robinson, Thierfelder (1994).

What is the research question? Much of the debate over NAFTA reflected concerns about potential wage changes as described by the Stolper-Samuelson theorem (SST). The theorem suggests that NAFTA will lower unskilled wages in the United States and raise those in Mexico as free trade causes the exports and prices of Mexico's unskilled labor intensive exports to increase, and the production and price of these goods in the United States to fall. However, wages in both countries are also influenced by the impact of NAFTA in increasing labor migration flows within Mexico and between Mexico and the United States. Could an applied CGE model of a free trade agreement between the United States and Mexico predict the wage effects from both SST effects and migration?

What is the CGE model innovation? The authors develop a CGE model of the United States and Mexico that allows labor migration between the two countries in response to changes in relative wages. The model also includes tariffs, and domestic taxes and subsidies that are not directly affected by the NAFTA accord and which create a second-best environment that violates many of the assumptions of the SST.

What is the experiment? The model experiments describe tariff elimination between the United States and Mexico in (1) a realistic model with tax distortions and (2) a distortion-free model that replicates some (but not all) of the assumptions of the SST. A trade liberalization experiment is run in the model without migration to explore SST effects, and in the model with labor migration to describe combined SST and factor endowment effects.

What are the key findings? The SST effects are found to be empirically very small, and labor migration has the dominant influence on wages in the free trade area, in some cases reversing the wage changes that would be expected based on the SST alone.

As an example, let's assume that the world price of agriculture (a capital-intensive good) has increased relative to the world price of manufactures (a labor-intensive good). To expand agricultural output, farmers must hire capital and labor from the manufacturing industry. As the manufacturing industry contracts, it releases both labor and capital, but the proportion of labor is too high and the proportion of capital is too low relative to the demands of agriculture. Given its scarcity, the increased demand for capital will push capital rents up while the surplus of labor will push wages down.

We depict these changes in the economywide demand for capital and labor in Figures 7.2a and 7.2b. In the figures, K describes the economy's supply of

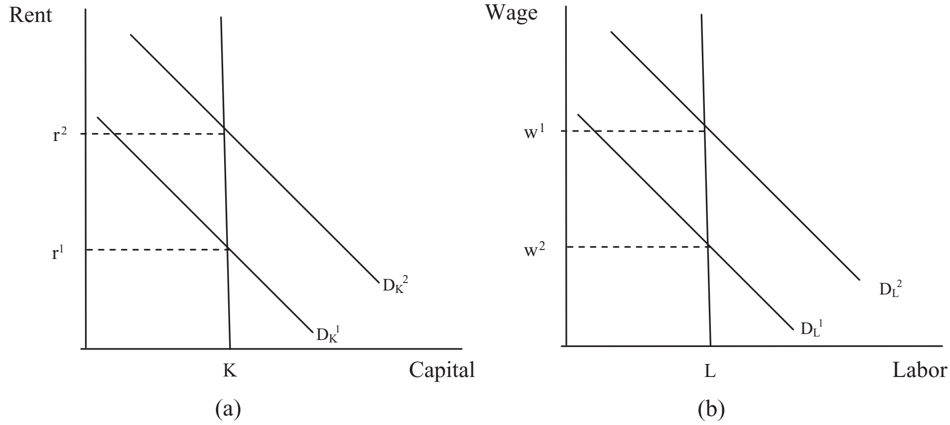

Figure 7.2. (a) Increase in economywide demand for capital due to an increase in the world price of the capital-intensive good. (b) Decrease in economywide demand for labor due to an increase in the world price of the capital-intensive good

capital, and L describes its supply of labor. Both supply curves are vertical because we assume fixed endowment quantities that are fully employed. In the initial equilibrium in Figure 7.2a, $D_K{}^1$ is the demand for capital and r^1 is the initial equilibrium rental rate. A shift in industry structure toward the capital-intensive industry increases the economywide demand for capital to $D_K{}^2$, causing the rental rate to increase to r^2. In the initial equilibrium in Figure 7.2b, $D_L{}^1$ is the demand for labor and w^1 is the equilibrium wage The shift in the country's industry structure toward the capital-intensive good causes the economywide demand for labor to fall to $D_L{}^2$ and the wage to decline to w^2.

We can use the Stolper-Samuelson theorem to understand the results of CGE model experiments that change world prices. As an example, we use the GTAP model with the U.S. 3x3 database to run an experiment that increases the world price of manufacturing by 10 percent. Based on our structure table in Chapter 3, we already know that U.S. manufacturing is relatively labor intensive. We might therefore expect that the increased world price of the manufactured good will lead to an increase in the U.S. wage relative to land or capital rents.

In our experiment, we find that that the production mix in the United States shifts toward manufacturing. Its output quantity increases 4.3 percent. Production of both agriculture and services decline. The shift toward production of a labor intensive product causes the U.S. wage to increase 7.7 percent, returns to capital to increase 7.5 percent, and the rental rate on land to decline 25.6 percent. The difference in impacts between wages and capital rents are very small but they are consistent with the predictions of the Stolper-Samuelson theorem.

Text Box 7.3. "Dutch Disease" in Cameroon
"The 'Dutch' Disease in a Developing Country: Oil Reserves in Cameroon."
(Benjamin, Devarajan, and Weiner, 1989)

What is the research question? Rising oil and gas prices confer substantial wealth on exporters of natural resources but these revenues can be a mixed blessing because they have the potential to cause deindustrialization, an unwelcome structural change known as "Dutch Disease." Most analyses of Dutch Disease have studied developed countries; how might a booming natural resource sector affect a developing country?

What is the CGE model innovation? The authors use a single-country CGE model of Cameroon that captures three key features of its economy: (1) agriculture, rather than manufacturing, is the traditional export sector (2) manufactured imports are imperfect substitutes for domestic varieties (i.e., they assume an Armington import aggregation function); and (3) the oil sector is an enclave so that, except for generating income, it has weak links to the rest of the Cameroonian economy.

What is the experiment? A boom in Cameroon's oil export industry is simulated as a $500 million inflow of foreign savings; an amount equal to its foreign oil export earnings in 1982.

What are the key findings? Similar to the experience of developed countries, Cameroon's economy experiences a structural change when its oil sector booms. Because the oil sector is an enclave, structural change is due mostly to the spending effect, as higher oil revenues increase incomes and demand, instead of the resource movement effect that pulls resources into oil production. However, instead of the deindustrialization that characterizes Dutch Disease, it is Cameroon's traditional agricultural sector that contracts.

Booming Sector, Dutch Disease

An increase in the world price of a country's export good would seem to offer it windfall benefits, but it can also lead to "deindustrialization," a problem that has received a great deal of attention from economists. This type of change in the production structure of an economy following an export boom has become known as ***Dutch Disease***, a reference to the deindustrialization that occurred in the Netherlands following its discovery of natural gas. The process was described more generally by Corden and Neary (1982) as the effects of a booming sector on the rest of the economy. Their analysis of an increase in the world price of a country's export is of interest to CGE modelers because it illustrates both the effects of a terms-of-trade shock on the country's industry structure as well as macroeconomic feedback through real exchange rate appreciation. Both are general equilibrium effects that CGE models are well-suited to analyze. (See Text Box 7.3.)

The Cordon-Neary model assumes a country with three sectors, capital that is fixed in each industry, and a labor force that is mobile among all three industries. Two sectors are traded – we'll call one of them oil (the booming sector) and call the other sector manufacturing. The third sector is services (including products like haircuts and lawn care), which are not traded. The country is small, so the prices of its oil and manufacturing are set by world markets. The price of its services is determined by domestic supply and demand.

A boom in the price of its oil export has two effects. The ***resource movement effect*** describes the reallocation of productive resources toward the booming sector. The increase in the export price enables the export sector to attract labor from manufacturing and services by paying higher wages. The country's industry structure then changes as the booming sector expands and output of services and manufacturing falls. Hence, the country begins to deindustrialize.

The ***spending effect*** results from the income growth due to higher export earnings. Higher income causes consumer demand for both services and manufactured goods to increase. Demand growth for manufactures can be met by increasing imports at the fixed world price but increased demand for services, which are not traded, can only be met by increasing domestic production. The spending effect therefore leads to further deindustrialization due to competition by the expanding services' sector for the resources used in manufacturing.

Both the resource movement effect and the spending effect lead to real exchange rate appreciation. The real exchange rate is the price of domestic services (a nontraded good) relative to manufactures (a traded good with a fixed world price). The fall in the supply of services in the resource movement effect creates a scarcity that causes the price of services to rise relative to the price of manufacturing. The spending effect leads to increased demand for services and an additional increase in the price of services relative to manufacturing. Because exchange rate appreciation makes imports more affordable, the appreciation linked to the spending and resource effects also contributes to increased imports and the decline in production of manufacturing.

To explore the Dutch Disease effects of a change in world prices in a CGE model, we use the GTAP CGE model with the U.S. 3x3 database to simulate a 10 percent increase in the world price of U.S. manufacturing (the booming sector). Our CGE model does not conform to all of the assumptions in the stylized model developed by Cordon and Neary. For example, our model includes intermediate demand and there is two-way trade in all three goods. Yet, the Dutch Disease framework remains useful because it informs us that the key effects of a boom (or bust) in world export prices are observed in changes in a country's industry structure, its real exchange rate, and trade.

Table 7.8. *Dutch Disease: 10 Percent Increase in the Rest-of-World Price of Manufacturing (% change from base values)*

	Production (*qo*)	Imports (*qiw*)	Exports (*qwx*)
Agriculture	−6.8	15.7	−34.5
Manufacturing	4.3	−4.8	15.6
Services	−0.7	14.4	−21.6

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

Based on the Dutch Disease model, we offer this prognosis for the U.S. economy: Output of U.S. manufacturing (the booming sector) will increase and agricultural output will decrease. However, the effect on output of services is ambiguous because the spending effect will tend to increase its output, but the resource movement and exchange rate appreciation will tend to decrease its output. We also expect that the U.S. real exchange rate will appreciate, causing foreign demand for all U.S. exports to fall, and U.S. demand for all imports to rise.

Results, reported in Table 7.8, show evidence of "disease" – the structural change that crowds out production in the nonbooming sectors. Output in the booming U.S. manufacturing sector increases, but output falls in both agriculture and services. The factor price exchange rate appreciates of almost 8 percent. U.S. import demand therefore increases for agriculture and services, but note that manufacturing imports fall. This is because the higher world price causes U.S. consumers to shift their demand toward the cheaper, domestic variety of manufactured goods. Exports of both agriculture and services fall because lower domestic production reduces the supply available for exports, and because exchange rate appreciation reduces foreign demand.

Trade and Transportation Margins in International Trade

Many multicountry CGE models and their underlying SAM databases explicitly account for the trade and transportation margin costs incurred in international trade. These costs include land, air, and sea freight costs, plus insurance and any other handling charges that are required to ship goods from the exporter's port to that of the importer. Trade and transport margins drive a wedge between the price received by the exporter and the price paid by the importer, and therefore can affect the quantity of trade. For example, the substantial decline in shipping costs since the 1950s is considered to be an important factor in explaining the rapid expansion of global trade over the

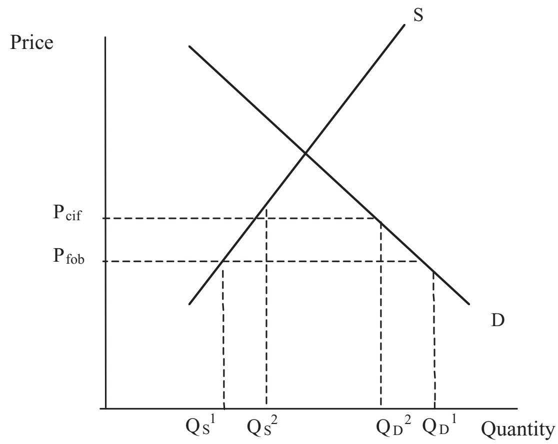

Figure 7.3. Import demand with trade and transport costs

past several decades.[5] There also can be shocks to shipping costs, which multi-country CGE models are well-suited to analyze. For example, Sullivan (2010) studied the effects of piracy off the East African coast that raised insurance and shipping costs for some commodities traded between certain partners. Jabara, Burfisher, and Ingersoll (2008) analyzed the bilateral trade effects of U.S. restrictions on the use of wood pallets to prevent the transoceanic introduction of invasive pests.

The effects of trade and transport margins on the quantity and prices of traded goods are illustrated in Figure 7.3, which describes a country's domestic supply and demand for good Q. In the figure, S is the small country's supply curve for the domestic production of Q, and D is its demand curve for the composite good, Q. Absent any margin costs, the country would produce Q_S^1 and import quantity $Q_D^1 - Q_S^1$ at a world price of P_{fob}. However, the inclusion of trade and transport margins increases the import price to P_{cif}, reducing the import quantity to $Q_D^2 - Q_S^2$ and causing domestic production to increase to Q_S^2. A shock that causes a change in margin costs would change the size of the trade margin cost per unit, $P_{cif} - P_{fob}$, and thus affect production and import quantities.

We explore the role of trade and transport margins in a CGE model by using the GTAP CGE model and the U.S. 3x3 database to run an experiment that reduces the margin costs on all U.S. imports. First, consider the initial import margin costs reported in the U.S. 3x3 SAM and replicated in Table 7.9. Margin services increase the cost of agricultural imports by 5.4 percent relative to their *fob* cost, and increase the cost of manufactured imports

[5] Hummels (2007), for example, found that U.S. air shipping costs declined by over 90 percent between 1955 and 2004, and ocean transport costs fell from 10 percent to 6 percent of import values over the past 30 years.

Table 7.9. *Effects of a Decline in Trade Margin Costs on U.S. Imports*

	Agriculture	Manufacturing
Base data		
Imports at *fob* price	167	1,203
Imports at *cif* price	176	1,250
Trade and transport margin	9	47
Trade margin rate	5.4	3.90
50% increase in productivity in trade margins (*atd*)		
U.S. import price *pcif* (% change)	−1.66	−1.25
U.S. import quantity *qiw* (% change)	2.61	2.66
U.S. production quantity *qo* (% change)	−0.79	−0.28
ROW export price *pfob* (% change)	0.06	0.01

Note: Trade margin rate is the trade margin cost as a percent of the *fob* value of imports.
Source: GTAP model, GTAP v.7.0 U.S. 3x3 database.

by 3.9 percent. Margin services are only required for trade in goods, not in services.

We model a reduction in the cost of margins as a 50-percent increase in productivity in trade margin services used for U.S. imports. This lowers the U.S. *cif* import prices for both goods, causing their import quantities to increase and their domestic production to fall. Notice that in our multicountry CGE model, the exporters' *fob* prices increase as a result of higher U.S. import demand, so U.S. *cif* import prices do not fall by the full amount of the reduction in margin costs. The benefits from the fall in margin costs therefore are split between the importer (the United States) and the exporter. The division of benefits of lower margin costs (or the burden of higher margin costs) between exporters and importers depends on the relative elasticities of the exporter's supply and the importer's demand.

Summary

Trade data in the SAM report trade valued in *fob* prices, import tariffs, export taxes, and the costs of trade and transport margins used in the international shipment of goods. Our discussion of trade behavior in a CGE model began by defining two concepts: the exchange rate and the terms of trade. The treatment of exchange rates differs among CGE models. The terms of trade measure a country's export prices relative to its import prices and describe the purchasing power of a country's export earnings. Terms of trade are thus a component in measuring changes in a nation's welfare. We used trade theory to ground our analyses of trade shocks in our CGE model. First, we relied on the Rybczynski theorem to explain the effects of an increase in a factor endowment on the commodity composition of trade and the subsequent effects on the terms of trade. The Stolper-Samuelson theorem informed our analysis of the effects of a change in world prices on a country's industry structure and factor prices. Our study of Dutch Disease explored a common problem in the world economy, in which a country experiences a change in its terms of trade (a boom or a bust for its main export) that causes changes in its industry structure. Finally, we explained how trade and transport margin costs affect trade volumes and world prices.

Key Terms

Dutch Disease
Heckscher-Ohlin theorem
Nominal exchange rate
Real exchange rate
Resource movement effect
Rybczynski theorem
Terms of trade
Spending effect
Stolper-Samuelson theorem

PRACTICE AND REVIEW

1. Suppose that technological innovation increases a country's capital productivity. It has two industries with the characteristics shown in Table 7.10:
   a. Which sector is capital intensive and which is labor intensive?
   b. How will the production of each sector be affected by an increase in capital productivity? Explain why.
   c. Which sector is exportable and which is importable?
   d. How do you expect imports and exports to be affected by the increase in capital productivity? How will this change in trade be likely to affect the terms of trade?
2. Venezuela is a developing country that derives much of its export earnings from oil. Use the Dutch Disease framework to explain the possible effects on production and trade of its nonoil industries following of a sudden hike in oil prices,

Table 7.10. *Industry Characteristics*

Industry	Capital Quantity	Labor Quantity	Production Quantity	Export Share of Production	Import Share of Consumption
Wine	142	1220	100	.50	.10
Televisions	97	25	100	.25	.40

Table 7.11. *Terms of Trade Exercises*

	U.S. Corn Exports		U.S. Oil Imports	
	Brazil	China	Saudi Arabia	Canada
Percent change in price	6	4	4	1
Market share	.6	.4	.8	.2

similar to that seen in summer 2008. What are the public policy issues that your analysis raises for Venezuelan policy makers?

3. Assume that a shock in world markets results in the price changes described in the Table 7.11. Using the information on market shares, calculate (1) the trade-weighted U.S. world export price (2) the trade-weighted U.S. world (*fob*) import price and (3) its terms-of-trade. Has the U.S. terms of trade improved or deteriorated?