Overview of a U.S. Multi-Regional Applied General Equilibrium Model

An applied general equilibrium (AGE) approach is appropriate for this analysis because changes in tax policy affect all industries of the economy at different rates. Furthermore tax changes affect disposable income and final demand. A multiregional framework is appropriate because State and Federal tax systems have very different effects, and thus tax reform is expected to have different consequences for different regions. Because there are close economic links between U.S. regions, it is appropriate to assess tax reform in a national framework.

Our general equilibrium approach is based on assumptions that are common in the literature (perfect competition, constant returns to scale, and full employment of resources). Also, our analysis is of a comparative static nature with medium-term economic adjustments. Our model is closely related to static AGE models already available for the analysis of international trade (for reviews, see Shoven and Whalley, 1984 and 1992; Francois and Shiells; and Hertel, Ianchovichina, and McDonald). Each regional economy, including the rest-of-the-world (ROW) region, is specified with demand and production structures. Subject to transportation costs, each U.S. region engages in commodity trade with other U.S. regions and the ROW region. Commodity prices are determined by market clearing through intraregional, interregional, and international trade.

To formulate a theoretically consistent quantitative model of those economic linkages, we are forced to reduce the dimensions of the problem. In particular, our regional and commodity specifications are shown in figure 2 and table 1. There are 10 aggregate regions representing the U.S. economy and the rest-of-the-world region representing all foreign economies. In terms of industry, there are seven aggregate industries (and commodities). Each of the three broad industries (agriculture, food processing, and manufacturing) includes a distinction between high-capital-intensity and low-capital-intensity industries. For example, grain production is represented by our high-capital agricultural industry. A seventh industry category represents all other economic activity. In terms of factor endowments, we specify 15 primary factors: farmland (noncorporate business), labor, shelter, and six types of capital (corporate and noncorporate). Labor and shelter are allocated to the residential sector.[2] To capture important differences in taxation,

[2]This specification obscures that shares of income from shelter are subject to corporate and noncorporate taxation. We do factor in these tax provisions, but choose to allocate only shelter to this sector.

Table 1—Commodity specification

Agriculture	**Manufacturing**	**Other industries**
Nongrain crops	Fabricated metal products	Coal
Other livestock	Leather, etc.	Construction
Wool	Lumber	Fisheries
	Machinery and equipment	Forestry
Agriculture, high capital	Nonferrous metals	Oil and gas
Grains	Nonmetallic minerals	Other minerals
Paddy rice and wheat	Other manufacturing	Water, gas, electricity
	Petroleum and coal	Trade and transportation
Food processing	Primary ferrous metals	Ownership of dwellings
Meat products	Pulp paper, etc.	Other services (government)
Milk products	Textiles	Other services (private
Other food products	Transport equipment industries	
Processed rice	Wearing apparel	
Food processing, high capital	**Manufacturing, high capital**	
Beverages and tobacco	Chemicals, rubbers, plastics	

we specify three sectors: corporate business, noncorporate business, and residential sectors. These sectors are used to classify and allocate all regional factor endowments for taxation.[3]

Some earlier analyses using multiregional AGE models were conducted by Kimbel and Harisson; Jones and Whalley, 1988, 1989, and 1990; Morgan, Mutti, and Partridge; Kraybill, Johnson, and Orden; and Buckley. Kimbell and Harisson developed a tax model to explore the effects of Proposition 13, using a California/rest-of-the-United States multi-industry framework. Their model allowed for complete mobility and substitution of some factor inputs, but no changes in interregional commodity flow patterns and without transportation costs.

Jones and Whalley (1988, 1989, and 1990) developed a multiregional AGE model for Canada. Their model has six Canadian regions and a rest-of-the-world region, 13 industries, and a combination of partially mobile and immobile primary factors. A notable mobile factor is labor, which may change its region of use and relocate its consumption to this new location. Labor is assumed to be internationally immobile, interindustry mobile, but interregionally partially mobile. The goods produced in each region were treated as qualitatively different from similar commodities produced either in other regions or abroad. Because of historical patterns of interregional trade subsidies and tariffs in Canada, the Jones/Whalley model did not include interregional transportation costs explicitly.

Morgan, Mutti, and Partridge developed a six-region general equilibrium model of the United States to assess the potential longrun effects of State, local, and Federal tax policies on output and the allocation of factors across regions and industries. At the most disaggregated level, the regionally differentiated traded goods were treated as highly substitutable but unique products. Transportation costs were ignored. Capital was assumed to be perfectly mobile across regions and industry, and it was reallocated until a common aftertax return emerges. The availability of labor in a region was assumed to be a function of real wages offered in that region relative to real wages available elsewhere.

Kraybill, Johnson, and Orden developed a two-region AGE model of the United States with five industry aggregates. Primary factor endowments (capital) are fixed at the regional (industry) level, as are regional government expenditures. Trade flows, including interregional domestic trade, are determined by relative prices and structural rigidities. They found that certain industries, including agriculture, bear a disproportionate burden of adjustment to macroeconomic imbalances, relative to other industries. The authors conclude that national level industry analysis underestimates such costs.

Buckley developed an interregional AGE model of the United States with three regions and five industries. The study differed from other multiregional AGE models in the explicit specification of intra- and interregional transportation and wholesaling services for bilateral trade in goods by industry. Buckley concluded that, relative to other approaches, the AGE's explicit specification provided a more focused description of the spatial economic effects that result from changes in economic conditions, such as transportation costs.

In this report, we present a multiregional AGE model, and we perform simulations of fundamental tax reform. The strengths of our approach are recent estimates of relevant tax policy instruments at the Federal and State/regional level and a theoretically consistent general equilibrium framework that builds on earlier works in this area. We focus on the comparative static implications of taxation under the assumption that the regional distribution of productive resources does not change. Improvements to this work may endogenize the level of productive resources (through savings and investment in a dynamic framework) or the regional distribution of some productive resources (through interregional migration).

Structure of the AGE Model

Each regional economy consists of several economic agents. First, a super-household, which is a combined public and private household (Hertel), supplies all primary factor services in the region and maximizes utility to determine commodity demands. Utility for the super-household comes from three general sources: private consumption financed by

[3]More specifically, these sectors are used for purposes of determining marginal factor tax rates, without implication of where the burden of this tax falls.

personal income, public consumption financed by Federal and regional government transfers, and regional savings. The concept of a super-household is convenient because it allows us to measure consistently the change in regional welfare. A second agent class encompasses the cost-minimizing industries that employ primary factor services and use intermediate products to produce commodities, each industry producing a single commodity. A third agent is a regional government that collects taxes from economic activity in the region. Finally, the U.S. Federal Government collects taxes from economic activity in all U.S. regions.

Regional income for the super-household consists of returns to primary factors (personal income), net regional taxes, and a transfer of funds from the U.S. Federal Government. The regional household saves part of its income and spends the rest to purchase private and public goods. By assuming that regional and Federal public goods are optimally supplied, we can focus on inefficiencies created by taxation.

Welfare and Household Behavior

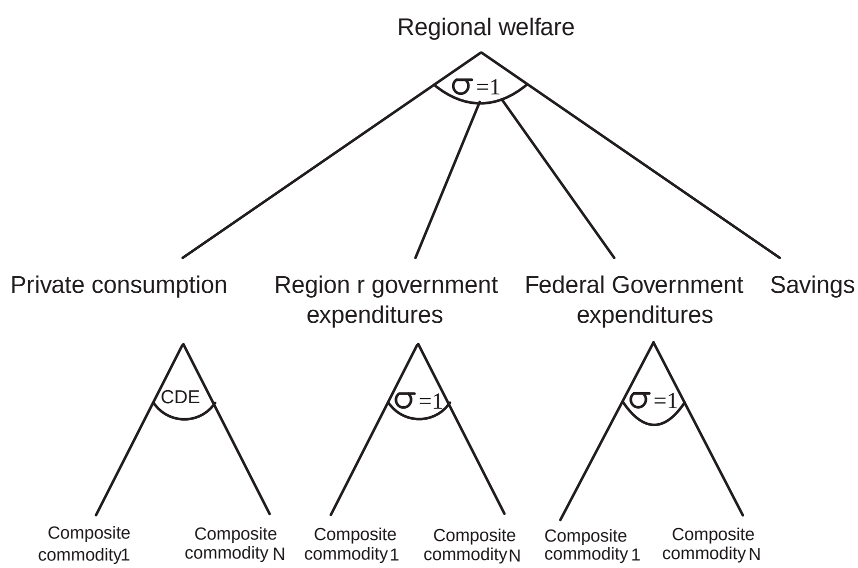
Figure 3 outlines a two-level utility tree for households in each region of the model. It is assumed that preferences are separable, which allows partitioning utility and commodities in subgroups that can be described independently of quantities in other groups. Thus overall utility may be expressed as a function of subutilities, which in turn have more subgroupings within them. The utility tree in figure 3 consists mostly of constant elasticity of substitution (CES) functions.

At the top of the utility tree (fig. 3), the concept of a super-household is implemented to model household decisions regarding expenditures and savings and to provide a theoretically consistent and comprehensive measure of welfare. The regional welfare implications of changes in exogenous variables, like tax policies, will be exactly reflected by changes in regional welfare. Regional welfare is derived from four components: private household expenditures, regional and Federal expenditures for public goods, and savings. In particular, each super-household maximizes utility subject to a regional income constraint. In the U.S. regions of the model, there are two types of public goods: regional/State and Federal. In the ROW, there is only one type of public good. It is assumed that the simulations we perform do not change the allocation of regional income across private and public goods, and savings.[4]

[4]This assumption is implemented by applying a Cobb-Douglas function to describe substitutions between the four components of welfare (in this case, the Allen partial elasticity of substitution, σ, is equal to *1*, and budget shares are constant).

Figure 3

Modeling of household welfare and expenditures



CDE: Constant difference in elasticities. σ: Partial elasticity of substitution in CES.

Household demands are determined separately for the two composite commodities. First, it is assumed that substitutions between composite public good commodities (Federal versus regional public goods) can be described with Cobb-Douglas functions. This simply implies that the relative expenditures between the regional and Federal composite commodities remain constant. Second, private household (that is, consumer) demands for composite commodities are based on the constant differences of elasticities (CDE) expenditure function.[5] The CDE specification allows for more flexibility in specifying varying degrees of substitution between consumer goods purchases. This specification is also less restrictive in how one specifies correlations between household wealth and private goods consumption patterns. For example, holding the relative price of all consumption goods constant, an increase in household wealth can lead to different rates of increase in each composite private good commodity, such as a less-than-proportionate increase in food consumption, and a more-than-proportionate increase in nonfood manufactured goods.

[5]The CDE expenditure function was developed by Hanoch (1975 and 1978), discussed by Surry (1989 and 1993), and implemented in AGE models by Hertel et al. (1991), and Hertel.

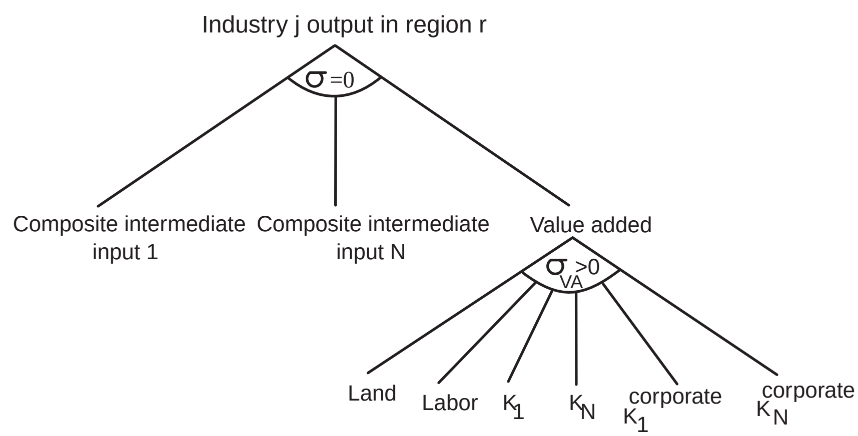
Industrial Demands

Producing industries demand two types of inputs: primary factors and intermediate inputs. The model treatment of substitution between inputs is outlined in the production tree in figure 4. The primary factor composite is a CES aggregate of land (where appropriate), labor, and several capital types. The CES, or constant elasticity of substitution, allows for substitution between factors of production in response to changes in relative factor prices. The elasticity of substitution between primary factors, σ_{VA}, is industry specific. There is no substitution between the primary factor composite and intermediate inputs (that is, a Leontief technology is assumed).

Interregional and International Trade

The main feature of the model treatment of trade is that intermediate (and final demand) users of commodities are assumed to treat imports from different sources as imperfect substitutes, that is, the Armington assumption is applied (Armington, 1969a and 1969b). Thus, demands reflect cost minimization across within-region and out-of-region sources of supply. One advantage of the Armington specification is that it allows one to account for the two empirical observations that, even at a very

Figure 4
Modeling of input substitutions in production



σ: Partial elasticity of substitution in constant elasticity of substitution technology.

disaggregated commodity level, economies import and export the same commodity and that most commodities are produced in all economies. The Armington assumption also allows for differing degrees of substitution between foreign and domestic goods across different commodities and for changes in relative prices of imported goods.

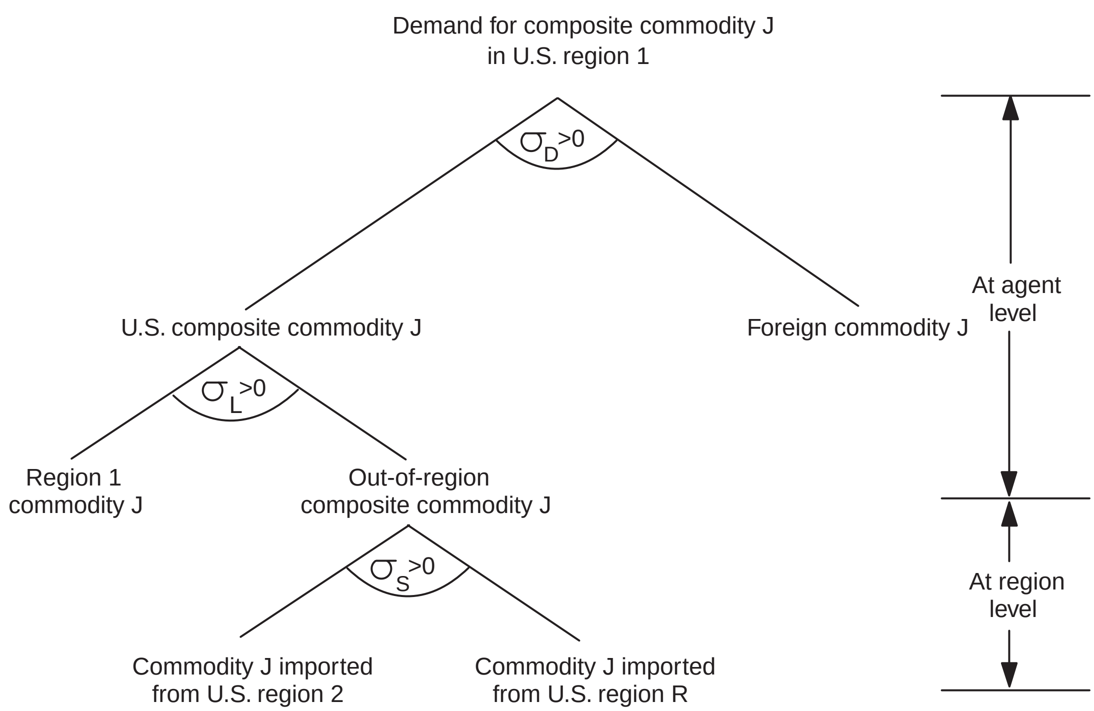
In figure 5, the elasticity of substitution $\sigma_L > 0$ determines the degree of substitution that occurs between within-region and out-of-region composite commodities. Within-region commodities are produced in the region. Out-of-region composite commodities are aggregates of imports from all other U.S. regions. Out-of-region and within-region varieties of the same commodity are aggregated to a domestic composite commodity. The elasticity of substitution $\sigma_D > 0$ determines the degree of substitution between the domestic composite variety and its foreign counterpart. This yields composite commodities for each commodity in the model. The top two levels in figure 5 implement the Armington assumption at the agent level. At the lowest level, the elasticity of substitution σ_S determines the degree of substitution across other regional sources of supply for each commodity. Substitutions at this level apply for the regional economy as a whole. Elasticities σ_D, σ_L, and σ_S are commodity specific.

The values of the substitution elasticities in figure 5 are important for model results on regional effects of policies. Elasticities of substitution between foreign imports and the domestic composite commodity (elasticity σ_D) largely determine the U.S. national import price elasticities of demand for each commodity. These elasticities determine the extent to which policies cause changes in the composition between foreign and U.S. domestic sources of supply, and thus they influence the national terms of trade. The values of elasticities of substitution between within-region and out-of-region varieties (elasticity σ_L) largely determine the extent to which a region's terms of trade improve or deteriorate due to a policy change. In addition to trade elasticities of substitution, the extent of trade and trade patterns also influences effects on terms of trade.

For each international transaction, there is a set of *ad valorem* tax (or subsidy) rates and therefore a set of world and regional prices. From an exporter's

Figure 5

Modeling of the Armington assumption



σ: Partial elasticity of substitution in constant elasticity of substitution technology.

point of view, the market price of a commodity will be different from its free on board (FOB) price when the exporting region gives an export subsidy. When the shipment of commodity reaches its region of destination, its customs, insurance, and freight (CIF) price may be different from its FOB price due to transportation costs. From the importer's point of view, the CIF price of an imported commodity may be different from its market price, in the importing region, due to import tariffs levied by the importing region.

There are two more aspects of the model that affect the interregional and international linkages in the model. First, a global industry demands services from each regional transportation services industry to provide a composite service used for transporting commodities across regions (Hertel). In value terms, each region's relative contribution to the global transportation industry does not change due to the simulation performed. It is also assumed that transportation services are required in fixed proportions with the quantity of a particular commodity shipped along a particular route.

Macroeconomic Closure

As in most comparative static AGE models, we face the problem of determining investment. In non-neoclassical closures, investment is fixed, and another variable adjusts to obtain a solution to the model. In this model, we apply a neoclassical closure: there is no independent investment relationship; investment simply accommodates any change in savings. Instead of applying this closure at the regional level, however, we apply this closure at the global level, using the concept of a global industry that intermediates between savings and investment. In each region, aggregate investment is represented by the output of a new capital goods industry. The global savings-investment industry has a portfolio of regional investments offered to regional households to satisfy their demand for savings. Globally, the sum of investment expenditures cannot be greater than the sum of household savings.

Regarding the regional composition of investment, the model offers two alternative allocation specifications. The first allocation specification assumes that the regional composition of global capital stock will not change due to the simulation performed. The second specification assumes that there is a negative relationship between the expected regional rate of return on capital and the amount of investment undertaken in a region. The global savings-investment industry manipulates this relationship until rates of return are equalized across regions. In the simulations that we perform at the end of this report, the second specification is applied and we examine the sensitivity of selected results to the investment allocation specification.

Primary Factor Mobility

Each region has a fixed endowment of land, labor, and capital assets. Labor services and services flowing from existing capital stocks are assumed to be mobile between industries, but region specific. This implies that all industries in a region face the same market price for labor services and the same market price for capital services. Regarding land, our approach allows for changes in industrial patterns of land use, but land rent differentials across industries are sustained. This assumption is implemented with a system of land supply functions derived from a constant elasticity of transformation function, with an elasticity of transformation $\sigma_T<0$.

Policies

A number of factors led to our choice of the 1994 tax policy and disposition of primary industrial factor markets for our base year. This is a tax year in which the significant reforms of the Revenue Reconciliation Act of 1993 were in place, most notably the changes in upper marginal tax brackets. The base year also immediately follows the year that the 1992 Economic Census and 1992 Census of Agriculture were enumerated, providing us with an extensive data resource based on surveys conducted in the year just prior to our year of analysis.

To encompass the multiple inefficiencies of the U.S. tax system, we employ linear tax instruments. This approach allows us to reconcile the total budget accounts for our tax base year of 1994, while explicitly modeling the marginal incentive effects of taxation. The relative size of the public sector directly affects the regional measures of welfare, as does the differential tax treatment of primary production factors and industry output.

Each regional household is endowed with all primary factors of regional production (fig. 6). All compensation that flows to these factors from regional industry (Level III) are owned by the household. All sources of taxation that fall on the personal income tax base (including property and output taxes) are explicitly modeled at their marginal effective rates, so the personal income tax depicted in Level V of figure 6 is a nondistorting intercept term, which forces the overall income tax rate to equal the actual 1994 rate on the relevant income tax base. Mathematically, if the total income tax base, $TB = \sum_{i=1}^{I} tb_i$, is taxed as the sum of I linear factor tax instruments and one *ad valorem* output tax instrument, total income tax revenue (T) equals $\left[\Sigma_{i=1}^{I} (a_i + b_i tb_i) + cTB\right]$ where a_i is the intercept (generally negative) of the linear factor tax, b_i is the slope (marginal effective tax rate) of the linear factor tax, and c is the flat output tax rate across all industry output.[6] Notice that linear factor taxes are progressive average taxes, which we calibrate to actual average tax rates, but that also reflect the marginal tax incidence on the factor income. It is straightforward to show that total tax revenue can be restated as,

$$T = \left[\frac{\sum_{i=1}^{I} a_i + cTB}{TB(1-\bar{b}_i)}\right] \text{x } TB(1-\bar{b}_i) + \sum_{i=1}^{I} b_i(tb_i),$$

where $\bar{b}_i$ is the weighted average marginal effective tax rate on factor incomes. Relating this to Level V in figure 6, the quotient within the squared brackets of the above equation is the personal income tax rate depicted in Level V, while the net of tax personal income depicted across Level IV of figure 6 is equal to $TB(1-\bar{b}_i)$ in the above equation. As depicted in figure 8, the b_i are marginal effective factor taxes, while tb_i are the gross of tax factor incomes.

The private household uses all the net proceeds (Level VI) to purchase consumption and investment goods (Level VII). This consumption/savings decision is determined by the relative prices of the two activities, based on a Cobb-Douglas preference specification. The decision to consume subjects the household to an *ad valorem* consumption tax, while the decision to save is indirectly subject to a tax on the price of savings (Level VIII).[7] The relative tax rates on consumption and investment goods will affect the household decision, and thus affect the level of household welfare (Level VIII). The consumption depicted in figure 6 is carried over to figure 7. For exposition, assume the final good on the top of figure 6 is the only good consumed by this household, and arbitrarily place this household in region *1* of a two-region U.S. economy. As depicted in figure 4, this consumer good is a composite of industrial output from domestic regions and the rest of the world. Moving to the bottom center of figure 7, note that for any industry i in region *1*, industrial output is directed to four areas (downstream industry within region *1*, downstream industry in other domestic regions, downstream international industry, final good markets). All industry i output shipped to international downstream industry may be taxed at the border, and this is treated as a separate border tax base. All domestically produced industrial output used in consumer goods are subject to an industry output tax, and all international industrial output used in consumer goods purchased by U.S. consumers is subject to a U.S. border tax. These taxes are represented in the model as *ad valorem* taxes and, except for border taxes, are assumed to be transmitted backward to the factor owners. It is assumed that no taxes are levied on shipments of industrial output to domestic downstream industries. Each region's tax burden on output includes Federal and State excise taxes and other fees that are proportional to output.

Industrial shipment proceeds must be allocated to factors of production.[8] This is depicted in figure 8. Payments to upstream industry for intermediate factors of production become part of the gross proceeds of industry j. Gross payments to labor lead

[6]Due to the level of industry aggregation, output taxes are viewed as nondistorting in this model, and so are modeled as an *ad valorem* tax on all output.

[7]In the model, the price of savings is the numeraire. The purchasing power of savings is the weighted average price of investment goods, which are in turn affected by factor and output taxes.

[8]Compensation of factors and from customers must be determined simultaneously. The sequential description here is arbitrary.

Figure 6
Sources of income and taxes from household capital and labor endowments

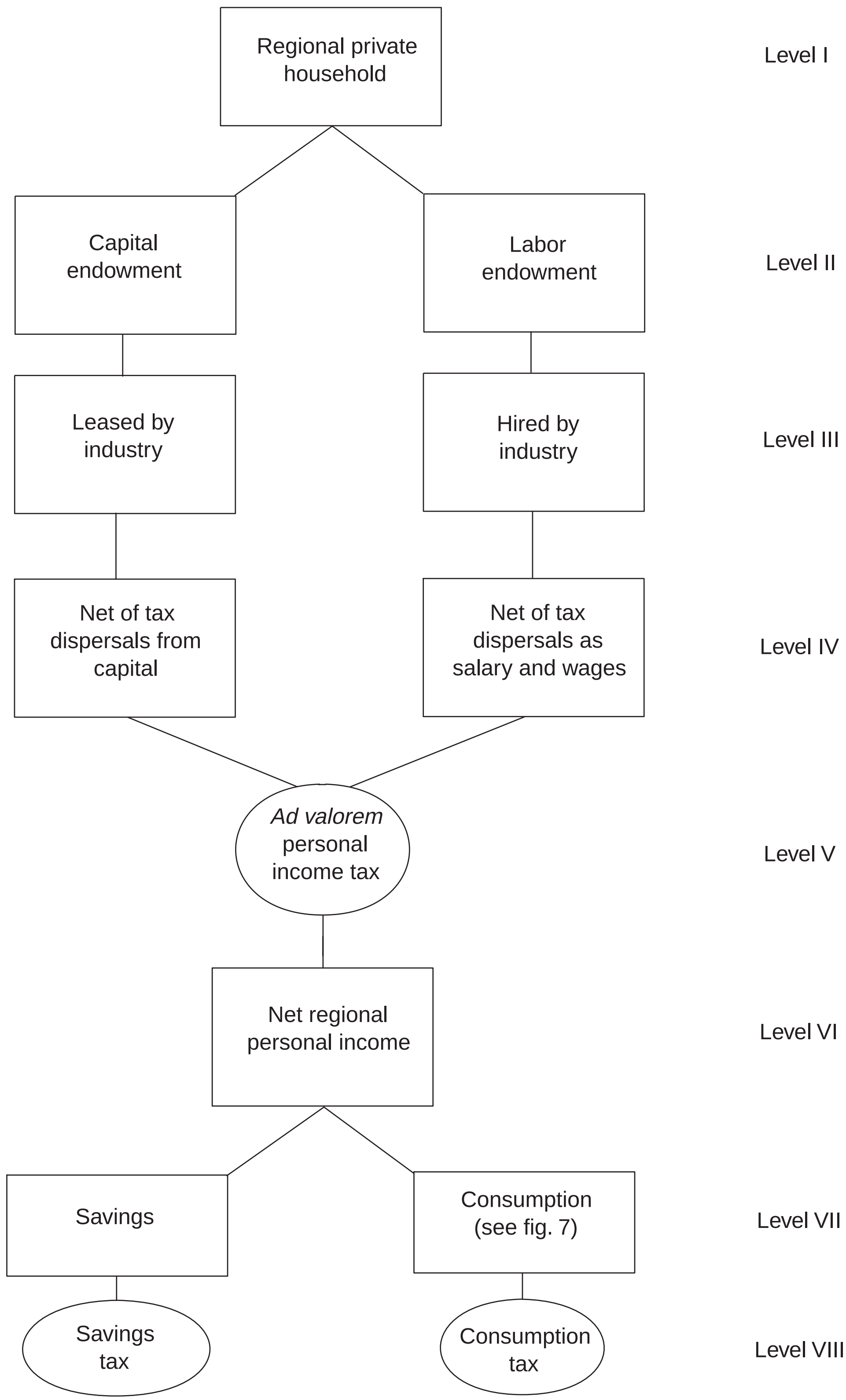
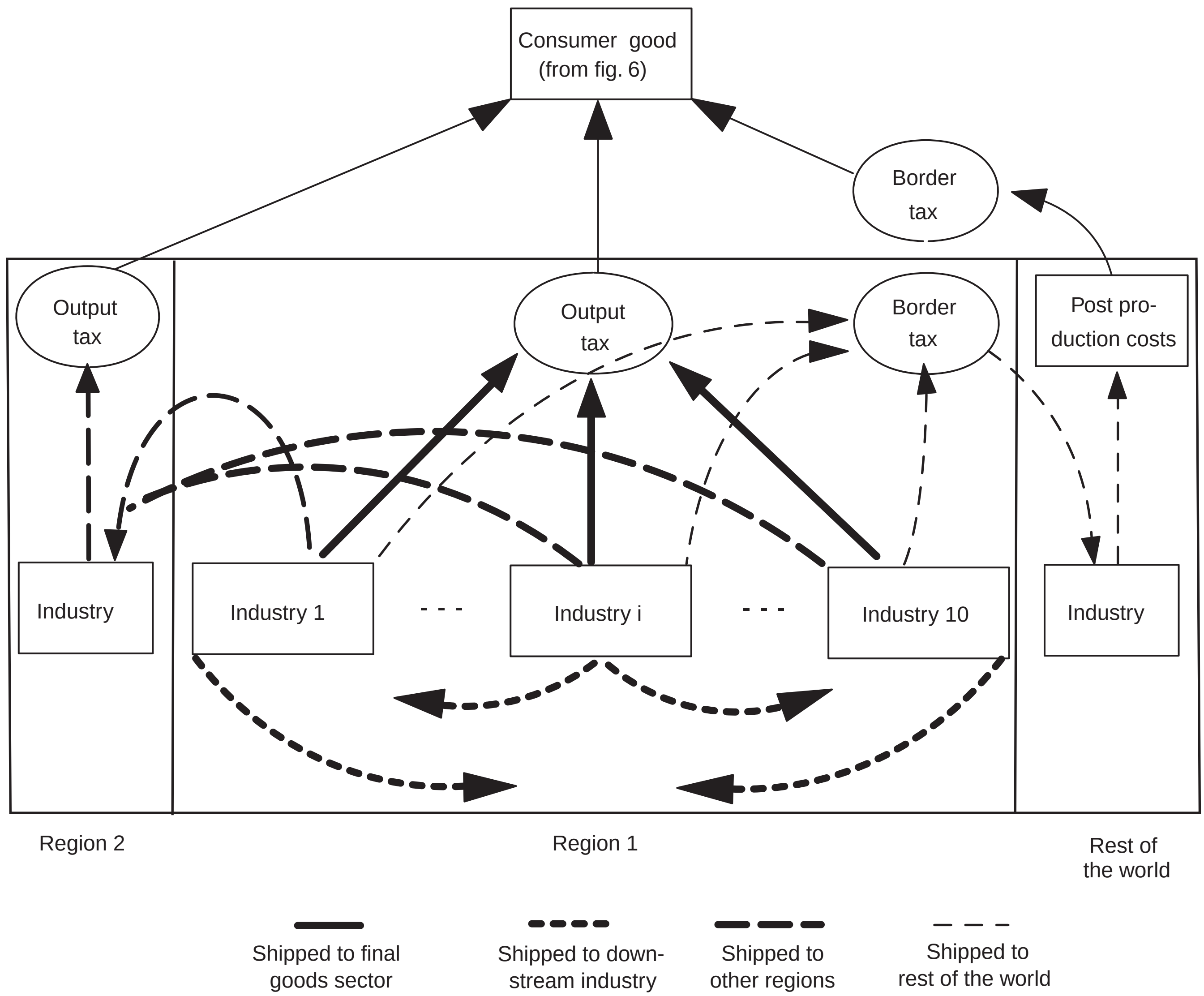


Figure 7
Sources of tax revenue in the industry/final-goods linkage

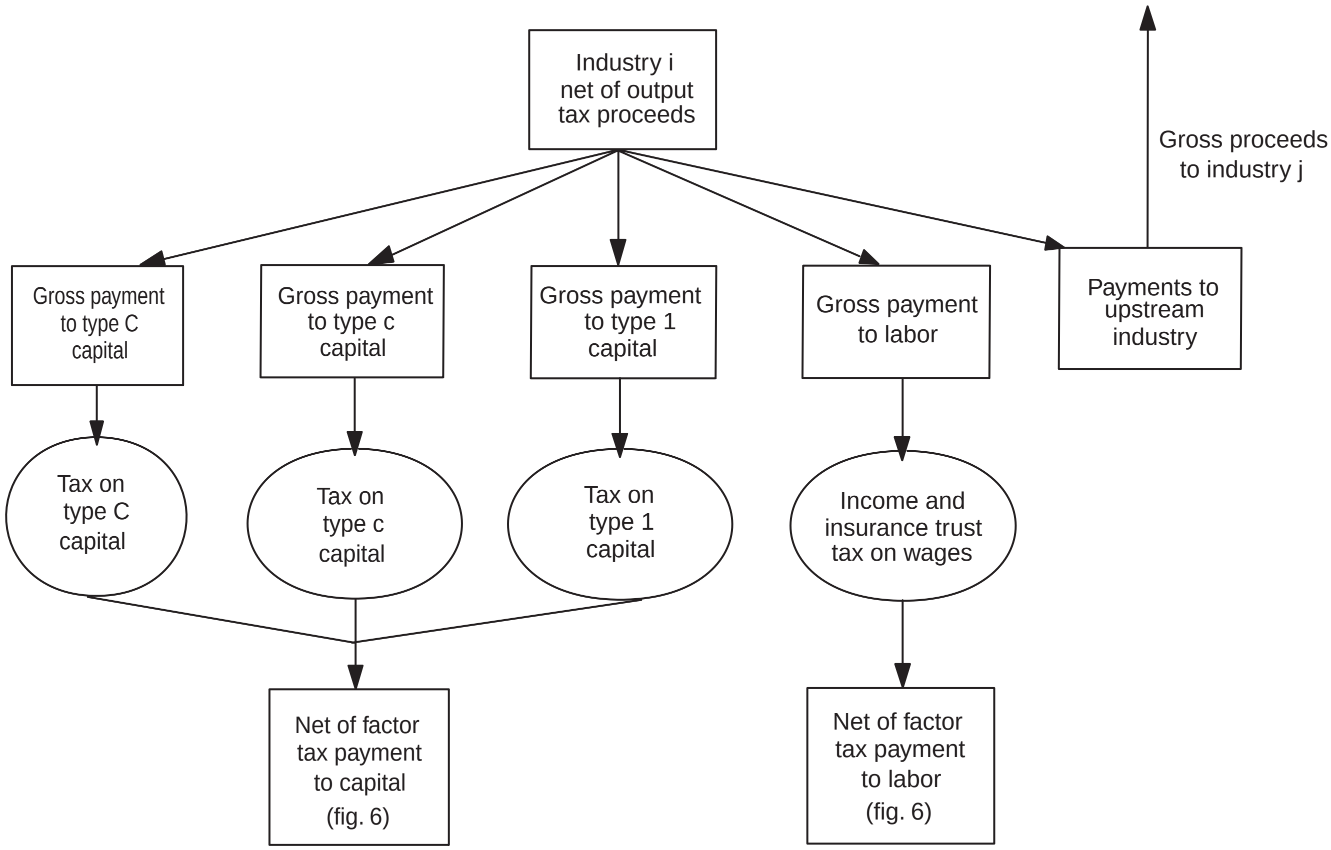


to a tax burden on industry *i* to cover Federal and State taxes, both for labor income and to cover Federal and State insurance trusts. This is represented as an *ad valorem* tax in the model, with a rate that reflects the weighted average marginal tax burden on regional labor income.[9] In other words, it is one of the b_i introduced at the beginning of this "Policies" subsection.

[9]One dollar of wage income is distributed to regional households in proportion to their existing wage income. Based on 1993 Federal and State income and insurance trust tax rules, new proceeds of these taxes from this dollar of income is divided by 100 to arrive at an average marginal wage tax rate.

While a single *ad valorem* tax on labor income is sufficient for calibration of the base year model, it is important to note that the labor factor tax has two components—income taxes and insurance trust taxes. These two tax instruments are computed separately and are additive at the margin. The purpose of this accounting procedure becomes more evident when we carry out tax reform simulations, since no serious tax reform scenarios propose harmonizing the insurance trust tax with other tax instruments. Our approach will be to leave the insurance trust tax, which is a pure wage tax, in place in all reform simulations not directly involving social security and/or medicare reform.

Figure 8
Sources of tax revenue in industry factor markets



What is not paid to labor and intermediates is paid to capital. In the model, there are 14 different classifications of capital, and for each type of capital in each region and for each of the 7 industry aggregates, there is a unique marginal tax rate, or a unique b_i. The method and measurement of these tax rates are discussed in the Taxation section and further explained in the appendix. The fact that each factor tax rate may be unique means the relative use of factors will be different from a scenario of no tax on factor incomes. Capital proceeds are allocated to each type of capital consistent with the requirement that net rates of return to the factor owner of each type of capital are equal. After factor taxes are deducted from industry proceeds, the net of factor tax payments to labor and capital is paid to factor owners, depicted in Level V of figure 6.

Public Expenditures

Government expenditures remain proportionally fixed to personal income. Since the budget shares of each government entity reflect household preferences, and because public and private consumption utilities are separable in the utility function, the cost-minimizing expenditures for each public good also remain proportionally fixed. In revenue-neutral tax simulations, public savings will vary inversely with the public good price index, nationally and regionally. This result is obtained in the model through both regional and U.S. Federal Government transfers of tax proceeds in fixed amounts to regional households.

Accounting Relationships

The model has a number of accounting relationships: market clearing for traded commodities and primary factor services, zero profit conditions, and income constraints for households. It is these economywide and global relationships that differentiate a partial from a general equilibrium model. One of these accounting relationships will be automatically satisfied when all the other accounting relationships are satisfied. This relationship is not included in the model, and the corresponding price is the numeraire in the model. In this model, the accounting relationship that is automatically met is that the sum of regional investment must equal the sum of regional savings. Therefore, the numeraire is the price of savings.

In the tax reform simulations that we perform in this bulletin, we require that the amount of taxes collected by the Federal and/or each regional government does not change. These government budget conditions are a part of the macroeconomic closure of the model.

The Database

To implement the model outlined in this section, initial equilibrium data and parameter values must be specified. The next two subsections describe the procedures applied to build a micro-consistent regional data set for the United States and the ROW, and the parameter values specified.

For each producing industry and household in the model, there are three separate vectors with expenditures, at agent prices: one for commodities produced within the region, one for composite commodities produced outside the region, and one for foreign imports. For each producing industry, there is also a vector with payments to primary factors. Corresponding vectors have data for these transactions evaluated at market prices. The sum of all payments for intermediate inputs and primary factors, at agent prices, gives the value of an industry's costs. The sum of expenditures by demanders, at market prices, shows total sales of commodities produced within the region and total exports. The sum of these two items gives total sales for a commodity. Total costs of each regional industry must equal total sales of the corresponding commodity produced within the region.

The trade data record bilateral trade flows between all regions and for all commodities. For each bilateral trade flow, there are four measures. Two measures are from the exporter's perspective: one evaluates exports at domestic market prices, and the other evaluates exports at world prices (FOB prices). The difference between these two measures is any export tax or subsidy. The other two measures are from the importer's perspective: one evaluates imports at world prices (CIF price), and the other evaluates imports at domestic market prices. The difference between the two measures is any import tariff duties. The difference between CIF and FOB values is due to transportation costs.

The 1987 input-output (IO) table of the U.S. economy (U.S. Department of Commerce, Bureau of Economic Analysis, 1994), the State-level employment statistics (U.S. Department of Commerce, Bureau of Economic Analysis, 1998b), and the State capital accounts (see the appendix) are the major building blocks in assembling regional economic accounts. To derive producer accounts for each U.S. State, statistics on employment by State were used along with our State capital accounts, and the assumption that for each industry/commodity, average output per unit of value added is the same across States. National private household expenditures are prorated across States using statistics on total personal income, by State (U.S. Department of Commerce, Bureau of Economic Analysis, 1999). U.S. national gross investment, by industry, was prorated across States using the computed State-level industrial output.

The IO table provides foreign import and export statistics for the U.S. economy as a whole. Two additional sources of information were used to describe trade linkages between U.S. States and those between U.S. States and the ROW. One of them is the Commodity Flow Survey statistics on interstate trade flows for commodities (U.S. Department of Transportation, Bureau of Transportation Statistics), and the other is the State Merchandise Export statistics (U.S. Department of Commerce, International Trade Administration). Both of those data sets are published at a very aggregated commodity specification. Therefore, it was necessary to prorate the trade data across commodities using regional production information. For the commodities not covered by the trade statistics, we assumed that regional trade patterns were similar to those for total trade.

The commodity flow survey provided the data for the value of shipments and ton-miles traveled by commodity for State of origin and the value of total shipments and ton-miles traveled by State of destination for State of origin. From the latter data, the composition of total exports by State of destination for State of origin may be computed.

Assuming that this composition is the same for all commodities, the data sources allow construction of bilateral trade flow matrices by commodity. Similarly, average ton-miles shipped for every trade transaction (that is, by commodity, State of origin, and State of destination) were computed. These data along with information on U.S. industry expenditures on transportation costs (from the IO table) allow construction of transportation cost information by commodity and trade route. Percentage transportation costs for international trade were obtained from the GTAP database (Gehlhar et al.).

The State merchandise export statistics provide the data for exports from the States to the ROW. For commodity aggregates for which the State export data do not have information, U.S. national exports were prorated across States.

The protection data refer to trade between the States and the ROW and are derived from the GTAP database (Gehlhar et al.). Those protection data include: (1) bilateral import tariffs derived from the original country submissions to the GATT for the Uruguay Round negotiations, (2) the Multi-Fiber Arrangement, (3) antidumping duties levied by Canada, the European Union, and the United States, (4) export subsidies for agricultural commodities, and (5) import nontariff barriers for agricultural and food commodities. The database also has import tariffs from the Uruguay Round agreement of the GATT.

Behavioral Parameters

In addition to the domestic and interregional data, the model requires specification of the behavioral parameters discussed in the "Welfare and Household Behavior" subsection. These parameters describe for each region utility-maximizing opportunities available to households, cost-minimizing opportunities available to producers, and import demands. Values for these parameters have been adopted from the SALTER (Jomini et al.) and GTAP (Huff et al.) modeling frameworks.

Demand systems for private households are based on CDE expenditure function. Ideally, one should obtain econometric estimates of the CDE parameters. However, it is rather difficult to estimate a CDE consumer demand system. Instead, the CDE is calibrated to price and income elasticities of demand from the econometric literature. This requires implementation of a calibration procedure outlined in Hertel et al. (1991) and Huff et al.

The first and second sections in table 2 show the demand elasticities for the private household in the model. As described in the "Welfare and Household Behavior" subsection, the elasticities in table 2 are based on the CDE functional form and are a function of the underlying CDE parameters and budget shares in the initial equilibrium. The substitution elasticities in table 2 show the Allen partial elasticities for the CES functions that describe substitutions among primary factor services in value added (see the "Industrial Demands" subsection) and in trade (see the "Interregional and International Trade" subsection).

The Intermediate Run

Policy simulations in the model assume a sufficient passage of time for existing production capacity within each economic region to be reallocated among industries. Reallocation exploits differential rates of return resulting from changes in parameter values. While this interindustry mobility can occur within each economic region, no such mobility exists across regions or between asset types (for example, transforming tractors into computers).

To motivate this intermediate-run scenario, we focus on capital factor markets. We have representation of four broad categories of capital—office machines, heavy machinery, transportation equipment, and industrial plants—each existing in the corporate and noncorporate form.[10] To maintain the production capacity made possible by this capital, a combination of regional public and private infrastructure must be in place to accommodate and service plant and machinery capacity and replace worn-out capital.

If a new fiscal policy regime were put in place (or some other change in economic conditions) that had differential effects across industry, sectors, capital types, and regions, we postulate a distinct ordering

[10]We will ignore land, utility plants, and residential structures in this discussion.

of industrial response. Starting from the end, assuming the new policy regime is perceived to be permanent, public and private sectors in regions that enjoy a distinct advantage in the new regime are likely to take measures to attract to their region (or in response to the attraction of their region) new investment capital so as to have in place a greater infrastructure for maintenance of higher capital (and labor) capacity. In the model, this possibility is addressed in our closure assumptions in the form of an international investment arbiter that allocates global savings regionally using one of two possible arbitration rules. This flow of funds foreshadows longrun effects of policy changes but has no real effects on regional production capacity. This is consistent with our assumption of asset fixity at the regional level, and a survey of industrial location research literature substantiates this assumption. For example, Blair and Premus conducted a literature survey that summarizes the prevalent empirical findings: "[M]ost local growth is attributable to differential growth rates of existing facilities. … The complete shutdown of a plant in one area in order to relocate to another area is rare" (p. 74). Global savings is directed to purchases of current specific industrial output in regions proportional to the planned future expansions (or retractions—for example, investment less than current period capital consumption).

Table 2—Model elasticities and parameters

Elasticities	Agriculture	Food	Manufacturing	Other industry	Agriculture, high capital	Food, high capital	Manufacturing, high capital
Compensated own-price elasticities:							
Appalachian	-0.09	-0.05	-0.76	-0.22	-0.01	-0.68	-0.88
Corn Belt	-0.09	-0.06	-0.76	-0.20	-0.01	-0.70	-0.87
Delta States	-0.07	-0.06	-0.72	-0.23	-0.01	-0.70	-0.86
Lake States	-0.09	-0.05	-0.76	-0.20	-0.01	-0.70	-0.89
Mountain	-0.08	-0.05	-0.77	-0.19	-0.02	-0.70	-0.88
Northeast	-0.09	-0.04	-0.76	-0.20	-0.01	-0.70	-0.90
Northern Plains	-0.08	-0.05	-0.76	-0.20	-0.02	-0.71	-0.88
Pacific	-0.08	-0.04	-0.79	-0.17	-0.01	-0.69	-0.88
Southeast	-0.09	-0.04	-0.75	-0.21	-0.01	-0.70	-0.88
Southern Plains	-0.09	-0.06	-0.73	-0.22	-0.01	-0.70	-0.87
Rest of world	-0.16	-0.17	-0.81	-0.19	-0.03	-0.51	-0.65
Income elasticities:							
Appalachian	0.65	0.62	1.03	1.04	0.60	0.98	1.06
Corn Belt	0.69	0.67	1.02	1.03	0.65	0.98	1.06
Delta States	0.68	0.66	1.02	1.03	0.64	0.98	1.06
Lake States	0.62	0.69	1.03	1.04	0.56	0.97	1.07
Mountain	0.65	0.63	1.02	1.03	0.61	0.97	1.06
Northeast	0.54	0.52	1.03	1.04	0.48	0.96	1.07
Northern Plains	0.55	0.54	1.03	1.04	0.51	0.96	1.07
Pacific	0.63	0.61	1.02	1.03	0.59	0.97	1.06
Southeast	0.57	0.54	1.03	1.04	0.52	0.97	1.07
Southern Plains	0.66	0.64	1.03	1.03	0.62	0.98	1.06
Rest of world	0.48	0.33	1.05	1.10	0.16	0.90	1.17
Substitution elasticities:							
S	10.33	8.80	12.68	9.21	8.80	12.40	7.60
L	5.10	4.40	6.12	3.96	4.40	6.20	3.80
D	2.53	2.20	3.13	1.99	2.20	3.10	1.90
VA	0.56	1.12	1.26	1.38	0.56	1.12	1.26

We assume that the passage of time required to get investment capital up and running is similar to the passage of time it takes to convert existing tractors into computers, or *vice versa*. Without taking this statement too literally, we simply mean that our broadly defined capital aggregates are sluggishly convertible. The same heavy machinery plant that produces farm tractors also produces construction cranes, and can transform tractor production to crane production timelessly, but with transformation limitations. On the other hand, current period shifts in regional demand for computer chips must be met using the region's office equipment capacity infrastructure, not through transformed heavy machinery capacity. Our partitioning of capital type aggregates is intended to reflect distinct operation infrastructure associated with each asset category.

Corporate, noncorporate, and residential capital cannot be transformed across sectors. This assumption is motivated by two factors. First, as noted in Fullerton and Henderson, many decisions related to incorporation and unincorporation reflect risk preferences and size considerations, and such factors are not explicitly represented in our model. Also, there is a paucity of regional data on corporate capital location, so it is difficult to make assertions about their mobility within a region, although we can allocate corporate capital regionally. As will be evident when we carry out policy simulations, even when national intersectoral shifts are small, regional level changes can be significant, and we chose to avoid the possibility of large regional intersectoral shifts in factors of production in our interpretation of the intermediate run. There is some theoretical justification for this assumption, as is often pointed out in the economic debates on the effect of capital gains taxation reform (see Auten and Cordes). Many have theoretically and empirically challenged the assertion that higher aftertax rates of return on corporate capital necessarily lead to higher rates of savings allocated to the corporate sector.

While each assumption employed in our representation of the intermediate run is subject to anecdotal counter examples, we believe that, collectively, they are an accurate representation of the intermediate response by economic agents to changes in economic factors. Further, our closure techniques provide a detailed foreshadowing of the longrun response, as would be explicitly captured in a dynamic policy simulation framework.

PC Implementation of the Model

To implement the model on a personal computer and perform simulations, a simulation program has been developed based on the GEMPACK suite of software (Harrison and Pearson). GEMPACK is designed to solve nonlinear economic models like this one. In particular, the model has been implemented in its linearized representation, and a solution consists of percentage changes in relative prices and quantities. GEMPACK obtains multistep solutions: a shock is broken up into several smaller pieces and, at each step, the linearized equations are solved for these smaller shocks. After each step, the data and price and income elasticities are recalculated to take into account the changes from the previous step. In general, the more steps a shock is broken into, the more accurate the solution will be. Pearson shows formally how a GEMPACK solution based on the linearized representation of a model can be as accurate as a solution of the underlying nonlinear model (Harrison and Pearson, appendix B; and Hertel, Horridge, and Pearson).