Chapter 19

Behavioral parameters

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This chapter describes how we obtained the initial estimates for the Global Trade Analysis Project (GTAP) behavioral parameters file. These include the source substitution or *Armington* elasticities, the factor substitution elasticities, the factor transformation elasticities, the investment parameters, and the consumer demand elasticities. Table 19.1 summarizes for these parameters: the associated notation, the set over which they are indexed, and their description. In this chapter we explain the role of each parameter in the GTAP model, and describe how we obtained the current settings.

Most of the parameters treated here enter directly into the GTAP data base. In contrast with the rest of the data file where an extensive and elaborate process of transformation is required to remove any inconsistencies, and repair the omissions in the initial data sets, no such processing is required here for most of the behavioral parameters. For the most part, each individual parameter is an independent datum, which stands or falls on its own, and does not require any consistency checks with other parameters. The one exception to this rule is the consumer demand parameters. Here we do need to check for consistency conditions — the triad of Engel aggregation, Cournot aggregation and symmetry condition. Also, there is a need to transform the data, from elasticities, for which we find empirical estimates, to the invariant parameters needed for our preferred functional form for the consumer demand system. We discuss the consistency conditions in this chapter. Discussion of the derivation of the consumer demand system invariant parameters (the so-called calibration problem) is deferred to chapter 21.

Table 19.1 Behavioral parameters in the GTAP model

	Parameters	Set index	Description
σ_{VA}	ESUBVA(j)	i∈ PROD_COMM	Elasticity of substitution between primary factors
σ_{D}	ESUBD(i)	i∈ TRAD_COMM	Elasticity of substitution between domestic and imported goods in the Armington aggregation structure for all agents in all regions
σ_{M}	ESUBM(i)	i∈ TRAD_COMM	Elasticity of substitution among imports from different destinations in the Armington aggregation structure of all agents in all regions
σ_{T}	ETRAE(i)	i∈ ENDWS_COMM	Elasticity of transformation for sluggish primary factor endowments.
	RORFLEX(r)	r∈ REG	Flexibility of expected net rate of return of capital stock in region r, with respect to investment
	RORDELTA		Binary coefficient which determines the mechanism of allocating investment funds across regions.
β	SUBPAR(i,r)	i∈ TRAD_COMM r∈ REG	The substitution parameter in the CDE minimum expenditure function
γ	INCPAR(i,r)	i∈ TRAD_COMM r∈ REG	The expansion parameter in the CDE minimum expenditure function

19.1 Source substitution elasticities

The data base contains two sets of source substitution elasticities. One relates to the substitution between domestic products and imports, and the other to the substitution between imports from different regions. To define these parameters precisely we need to refer to the theoretical structure of the GTAP model. In that model, the source substitution elasticities are defined separately for each of the representative agents within each region rather than referring to a single economy-wide demand behavior, as in the other models. This means that for each commodity within each region, the domestic-import mix is determined separately for each industry, and for each of the final demand categories, namely investment, household consumption, and government consumption. The sourcing of imports is also determined separately, for intermediate usage (for all industries together) and for each of the final demand category. Finally, for cross-regional behavior, the GTAP model assumes that for each commodity, all agents in all regions display the same substitution elasticity.

The source substitution elasticities for GTAP are taken from the SALTER model (Jomini *et al.* 1991). Since GTAP derives its sectoral classification from SALTER, we can adopt the SALTER parameters without any remapping of the commodities. The settings adopted here are shown in the second and third columns of table 19.2. The SALTER settings represent a compromise between econometric evidence and prior belief. A search of the econometric literature indicated that these elasticities are relatively low. On prior belief, it is generally believed that the terms of trade effects of commercial policy changes are generally quite weak. Such weak terms of trade effects imply that the source substitution elasticities are relatively high. The SALTER settings adopted here, thus, represent a compromise: the elasticities are generally higher than that indicated by the econometric literature, but still low enough to generate significant terms of trade effects (Jomini *et al.* 1991).

An aspect of the SALTER compromise is a divergence between domestic-import and import-import substitution elasticities. The econometric evidence related mostly, though not entirely, to domestic-import substitution. On the other hand, the terms of trade effects depend largely on the import-import substitution elasticities (if these are high, then a given region can displace other regions in its export markets without greatly reducing its export prices). By setting the import-import substitution elasticities higher than the domestic-import substitution elasticities, one can reconcile the low domestic-import substitution elasticities with the weak terms of trade effects. After reviewing a fairly sparse literature on import-import substitution elasticities, the SALTER team concluded that these might plausibly be set at a level twice as high as the import-domestic elasticities.

In summary, the SALTER elasticities were set as follows: the domestic-import substitution elasticities were based on preferred estimates from the econometric literature with some upward adjustment. The import-import substitution elasticities were then set at twice the domestic-import substitution elasticities. This procedure has been brought over without change into GTAP (see table 19.2). However, it may be of interest to observe that in long-run projections applications, GTAP staff have commonly increased the standard settings of these parameters. This is based on Gehlhar's observation that increasing the trade elasticities improved the fit of the model to East Asian trade shares over the 1980's (Gehlhar, 1994).

19.2 Factor substitution elasticities

The nested CES production functions in the GTAP model are similar to those used in many other applied general equilibrium models. Primary factors of production are assumed to substitute for one another according to the constant elasticity of substitution, σ_{VA}, while composite value-added and intermediates are used in fixed proportions. The overall elasticity of substitution among primary factors determines the ability of the economy to alter its output mix in response to changes in relative prices, or changes in the endowments of these factors. These parameters also play an important role

in determining the sectoral supply response in the presence of sector-specific and sluggish factors of production. For example, with the supply of agricultural land bing fixed in the model, the ability to expand farm output can be directly linked to the ease of substitution between land and labor, and land and capital.

The first column of table 19.2 reports the assumed values for σ_{VA} for each of the GTAP sectors. Like the trade elasticities, these are taken from the SALTER parameter file (Jomini *et al.* 1991). They are based on a review of the international cross-section studies which estimated this parameter, for various industries, using data from a wide range of countries. Note the relatively small elasticity of substitution in primary production. In light of the discussion regarding the linkage between this parameter and the sectoral supply response in the face of sector-specific factors, we can infer that whenever sector-specific, or sluggish factors of production are present in these sectors, this will significantly constrain the supply response of the sectors. Finally, we note that the greatest degree of substitutability (1.68) arises in the trade and transport sector.

19.3 Factor transformation elasticities

The third class of behavioral parameters in GTAP describes the degree of primary factor mobility between the sectors. Within each region, the model distinguishes between primary factors that are perfectly mobile across productive sectors and those that are sluggish. In an experiment with sluggish factor endowments, it is important to find out *how much of a disparity in relative sectoral returns can be sustained over the simulation period.* This result is governed by the value of the elasticity of transformation, $\sigma_T < 0$. If σ_T is close to zero, then the allocation of factors across sectors is nearly fixed, and therefore factor supply is unresponsive to changes in relative returns. As σ_T takes on larger negative values, then the supply of factors will become more and more responsive to relative returns [see equation (51) in table 2.14 of chapter 2 in Hertel and Tsigas (1997)]. In the limit, as $\sigma_T \rightarrow -\infty$, this factor is perfectly mobile and no differential return can be sustained over the time horizon envisioned in the simulation. In this case, the factor should be reclassified as a perfectly mobile factor.

In the default setting which is generated from a standard aggregation of the data base, skilled and unskilled labor and capital are treated as perfectly mobile, whereas natural resources and agricultural land are treated as sluggish factors of production. Since the latter inputs are used only in agricultural activities, their sluggishness is relevant only if the aggregation in question contains more than one farm sectors.

19.4 Investment flexibility parameters

Investment flexibility parameters refer to the degree of flexibility of regional investment. In the GTAP model, if the user chooses to allow the allocation of global investment to regional economies to be responsive to region-specific rates of return on capital (parameter *RORDELTA* is 1), then the parameter *RORFLEX*(*r*) > 0 must be properly specified [equation (58) of table 2.15 in chapter 2 of Hertel and Tsigas (1997)]. The smaller the value of *RORFLEX*(*r*), the greater the responsiveness of international investment to a change in the rate of return in region *r*. Because *RORFLEX*(*r*) is indexed over regions, it is possible to have some regions where investment is quite sensitive to changing rates of return, and others where this is not.

19.5 Consumer demand elasticities

GTAP employs the constant difference of elasticities (CDE) functional form in the specification of private household demands. The CDE, introduced by Hanoch (1975), can be classified as somewhere between the nonhomothetic CES and more flexible functional forms. It is based on the assumption of implicit additivity and allows for a richer representation of income effects on the demand system. The CDE implicit expenditure function is given by:

$$\sum_{i \in TRAD} B(i,r) * UP(r)^{\beta(i,r)\gamma(i,r)} * [\, PP(i,r) / E(PP(r), UP(r))\,]^{\beta(i,r)} \equiv 1.$$

where E(.) represents the minimum expenditure required to attain a prespecified level of private household utility, UP(r), given the vector of private household prices, PP(r). Individual prices are normalized using minimum expenditure and then raised to the power β(i,r) and combined in an additive form. The calibration problem (discussed in chapter 21) involves choosing the values of the substitution parameter, β(i,r) or SUBPAR(i,r), to replicate the desired compensated, own-price elasticities of demand, then choosing the expansion parameters, γ(i,r) or INCPAR(i,r) to replicate the targeted income elasticities of demand. In this section, we document the sources and assumptions behind the estimates of the commodity and region-specific income and price elasticities of demand that are used as targets in the CDE calibration procedure.

We draw on the available estimates of income elasticities from cross-country demand studies for an adaptation to the GTAP's 50 sectors and 45 regions. Cross-country demand studies are preferable over single country demand studies since they provide demand elasticity estimates which are consistent across countries in terms of data and estimation procedure used. These cross-country

consumer demand studies typically carry the assumption of preference independence, and hence of additivity, in the utility function when specified in terms of broadly defined commodity groups. In adapting income elasticity estimates to the GTAP data base, we must allocate the estimates from the more aggregate commodity groupings in these demand studies to our more disaggregated commodity classification.

Income elasticities of demand. Two studies provide recent income elasticity estimates which have more adequate country and commodity coverage for use with the disaggregate GTAP sectors and region. These are the World Food Model of the Food and Agriculture Organization (FAO, 1993) and the cross-country demand study by Theil, Chung, and Seale (1989). The income elasticity estimates used in World Food Model (WFM) were themselves obtained from the literature, or estimated using simple econometric models. The WFM covers 147 countries and 13 agricultural commodity groups, namely: wheat, rice, maize, millet and sorghum, other coarse grains, total fats and oils, bovine/cattle, sheep and goat, pig, poultry, diary products excluding butter, and butter. The Theil, Chung and Seale study (TCS) used the 1980 consumption data for 51 countries from phase IV of the International Comparison Project (ICP). Assuming preference independence, consumption data was fitted to Working's model of consumption expenditures defined for 10 broad commodity aggregates. The commodity aggregates are food, beverages and tobacco, clothing and footwear, gross rent and fuel, house furnishings and operations, medical care, transport and communications, recreation, education, and others.

The income elasticity estimates for food and for the commodity aggregates are mapped into the GTAP's 50 commodities according to the commodity concordance shown in table 19.3. The income elasticity estimates for food were adapted mostly from the FAO World Food Model. The income elasticity estimates for nonfood commodities were obtained from a mapping with the broad commodity aggregates in the TCS study. In adapting all of these estimates to GTAP, we used 0.10 as the lower bound for income elasticities because smaller values can cause calibration problems for the CDE function. For example, 0.10 is used as the income elasticity for rice for which a negative value is otherwise reported for some regions, e.g. Japan.

GTAP's 45 regions also had to be mapped with the countries covered by WFM and TCS to arrive at income elasticity estimates at the regional level. For GTAP single regions that are not covered by these studies, we used estimates for other single regions with similar per capita GDP. This regional concordance between GTAP and the WFM and TCS countries is shown in table 19.4. Since "China" in the WFM covers both the People's Republic of China (PRC) and Taiwan and since China is not covered in the TCS study, the results of more recent econometric work which are separately based on either urban or rural household surveys was used in obtaining income elasticity estimates for the PRC. Income elasticity estimates for food commodities for urban households were obtained from Chern and Wang (1994) and for broad commodity aggregates from Zhi and Kinsey (1994). For the rural households, we adapted the income elasticities estimated by Fan, Wailes, and Cramer (1995) using a 2-stage LES-AIDS model on 5 broad commodity aggregates in the first stage and on disaggregate food commodities in the second stage. A mapping of the broad commodity

aggregates to GTAP's 50 sectors was also required before getting the average of the urban household and rural household income elasticity estimates for GTAP's China region.

The matrix of income elasticity estimates for 50 commodities and 45 regions are used in the CDE calibration procedure described in chapter 21 and in generating estimates of the own-price elasticity of demand as described below.

Price elasticities of demand. The cross section studies mentioned above are not in a strong position to generate information on price elasticities of demand. Reliable price data can be difficult to be obtained, and, as noted above, most of these studies simply assume additive preferences, which means that the price elasticities of demand are determined simply by the income elasticity in conjunction with a single substitution parameter. For this reason, we do not attempt to specify the price elasticities of demand for all of the commodities in all of the regions. Instead, we use the relationship for directly additive preferences proposed by Frisch (1959) and embodied in the Linear Expenditure System (LES). As discussed in Huff *et al.* (1997), the CDE is a more flexible functional form than the LES, and we could have used independent information on own-price demand elasticities in this calibration had it been available. In the future, we hope to supplement the elasticities file with cross-country studies of own-price responses. In addition, by using the CDE, GTAP modelers are given the flexibility to adjust commodity-specific substitution effects to conform with outside information on own-price elasticities of demand for key commodities in any particular application.

Using the income elasticity estimates, the values for own-price elasticities of demand were computed following the procedure and formula outlined in Zeitsch et al. (1991):

$$\epsilon_{ii} = -s_i \eta_i \left(1 + \frac{\eta_i}{\omega}\right) + \frac{\eta_i}{\omega},$$

where ϵ_{ii} is the uncompensated own-price elasticity of demand for commodity *i*; η_i is the income elasticity of demand for commodity *i*, s_i is the expenditure share of commodity *i*, and ω is the Frisch parameter, that is, minus the reciprocal of the marginal utility of income, or the money flexibility. The compensated own-price elasticities, v_{ii}, are then computed as:

$$v_{ii} = -\epsilon_{ii} + s_i \eta_i$$

Using the above methods, we end up with estimates for income and compensated own-price elasticities of demand for 50 commodities and 45 regions that can be used as targets in the CDE calibration procedure discussed in chapter 21.

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Table 19.2 GTAP substitution elasticities

GTAP commodities	Value-added (σ_{VA})	Domestic/ imported (σ_D)	Sourcing of imports (σ_M)
Paddy rice	0.24	2.20	4.40
Wheat	0.24	2.20	4.40
Cereal grains nec	0.24	2.20	4.40
Vegetables, fruit, nuts	0.24	2.20	4.40
Oil seeds	0.24	2.20	4.40
Sugar cane, sugar beet	0.24	2.20	4.40
Plant-based fibers	0.24	2.20	4.40
Crops nec	0.24	2.20	4.40
Cattle, sheep and goats, horses	0.24	2.80	5.60
Animal products nec	0.24	2.80	5.60
Raw milk	0.24	2.80	5.60
Wool, silk-worm cocoons	0.24	2.20	4.40
Forestry	0.20	2.80	5.60
Fishing	0.20	2.80	5.60
Coal	0.20	2.80	5.60
Oil	0.20	2.80	5.60
Gas	0.20	2.80	5.60
Minerals nec	0.20	2.80	5.60
Cattle, sheep and goat, horse meat	1.12	2.20	4.40
Meat Products nec	1.12	2.20	4.40
Vegetable oils and fats	1.12	2.20	4.40
Dairy products	1.12	2.20	4.40
Processed rice	1.12	2.20	4.40
Sugar	1.12	2.20	4.40
Food products nec	1.12	2.20	4.40
Beverages and tobacco products	1.12	3.10	6.20
Textiles	1.26	2.20	4.40
Wearing apparel	1.26	4.40	8.80
Leather products	1.26	4.40	8.80
Wood products	1.26	2.80	5.60
Paper products, publishing	1.26	1.80	3.60
Petroleum , coal products	1.26	1.90	3.80
Chemicals, rubber, plastic pro	1.26	1.90	3.80
Mineral products nec	1.26	2.80	5.60
Ferrous Metals	1.26	2.80	5.60
Metals nec	1.26	2.80	5.60
Metal products	1.26	2.80	5.60
Motor vehicles and parts	1.26	5.20	10.40
Transport equipment nec	1.26	5.20	10.40
Electronic equipment	1.26	2.80	5.60
Machinery and equipment nec	1.26	2.80	5.60
Manufacture nec	1.26	2.80	5.60
Electricity	1.26	2.80	5.60
Gas manufacture, distribution	1.26	2.80	5.60
Water	1.26	2.80	5.60
Construction	1.40	1.90	3.80
Trade, transport	1.68	1.90	3.80
Financial, business, recreational services (private)	1.26	1.90	3.80
Public admin and defense, education, health	1.26	1.90	3.80
Dwellings	1.26	1.90	3.80

Source: Jomini *et al.*, table 4.3, 1991.

Table 19.3 Commodity classification concordance for income elasticity estimates, by source: FAO's World Food Model (WFM) and the Theil, Chung and Seale study (TCS)

GTAP commodities	Commodity groups	Source
Paddy rice	rice	WFM
Wheat	wheat	WFM
Cereal grains nec	weighted average [a]	WFM
Vegetables, fruit, nuts	food (aggregate)	TCS
Oil seeds	food (aggregate)	TCS
Sugar cane, sugar beet	food (aggregate)	TCS
Plant-based fibers	food (aggregate)	TCS
Crops nec	food (aggregate)	TCS
Cattle, sheep and goats, horses	cattle and sheep	WFM
Animal products nec	pig and poultry	WFM
Raw milk	dairy products	WFM
Wool, silk-worm cocoons	0.5 * clothing and footwear	TCS
Forestry	other	TCS
Fishing	food (aggregate)	TCS
Coal	gross rent and fuel	TCS
Oil	gross rent and fuel	TCS
Gas	gross rent and fuel	TCS
Minerals nec	gross rent and fuel	TCS
Cattle, sheep and goat, horse meat	cattle and sheep	WFM
Meat Products nec	pig and poultry	WFM
Vegetable oils and fats	total fats and oils	WFM
Dairy products	dairy and butter	WFM
Processed rice	rice	WFM
Sugar	food (aggregate)	TCS
Food products nec	food (aggregate)	TCS
Beverages and tobacco products	beverages and tobacco	TCS
Textiles	clothing and footwear	TCS
Wearing apparel	clothing and footwear	TCS
Leather products	other	TCS
Wood products	other	TCS
Paper products, publishing	other	TCS
Petroleum , coal products	other	TCS
Chemicals, rubber, plastic products	other	TCS
Mineral products nec	other	TCS
Ferrous Metals	other	TCS
Metals nec	other	TCS
Metal products	other	TCS
Motor vehicles and parts	transport and communications	TCS
Transport equipment nec	transport and communications	TCS
Electronic equipment	house furnishings and operations	TCS
Machinery and equipment nec	house furnishings and operations	TCS
Manufacture nec	house furnishings and operations	TCS
Electricity	gross rent and fuel	TCS
Gas manufacture, distribution	gross rent and fuel	TCS
Water	gross rent and fuel	TCS
Construction	gross rent and fuel	TCS
Trade, transport	transport and communications	TCS
Financial, business, recreational services (private)	recreation	TCS
Public admin and defense, education, health	linear average [b]	TCS
Dwellings	gross rent and fuel	TCS

[a] Weighted average of WFM income elasticities for maize, sorghum and millets, and coarse grains.

[b] Linear average of TCS income elasticities for medical care and education.

Table 19.4 Concordance of GTAP regions with WFM and TCS countries

GTAP regions	WFM countries	TCS countries
Australia	Australia	*Canada*
New Zealand	New Zealand	*Israel*
Japan	Japan	Japan
Korea, Rep. of	Korea, Rep. of	Korea, Rep. of
Indonesia	Indonesia	Indonesia
Malaysia	Malaysia	*Hungary*
Philippines	Philippines	Philippines
Singapore	Singapore	*United States*
Thailand	Thailand	*Panama*
Viet Nam	Viet Nam	*Madagascar*
China	*N.A.*	*N.A.*
Hong Kong	Hong Kong	Hong Kong
Taiwan	*Spain*	*Portugal*
India	India	India
Sri Lanka	Sri Lanka	Sri Lanka
Rest of South Asia	*linear average* [a]	*linear average* [a]
Canada	Canada	Canada
United States	United States	United States
Mexico	Mexico	*Panama*
Central America and the Caribbean	*linear average* [a]	*linear average* [a]
Venezuela	Venezuela	Venezuela
Colombia	Colombia	Colombia
Rest of Andean Pact	*linear average* [a]	*linear average* [a]
Argentina	Argentina	Argentina
Brazil	Brazil	Brazil
Chile	Chile	Chile
Uruguay	Uruguay	Uruguay
Rest of South America	*linear average* [a]	*linear average* [a]
United Kingdom	United Kingdom	United Kingdom
Germany	Germany	Germany
Denmark	Denmark	Denmark
Sweden	Sweden	*Netherlands*
Finland	Finland	Finland
Rest of European Union	*linear average* [a]	*linear average* [a]
European Free Trade Area	*linear average* [a]	*Norway*
Central European Associates	*linear average* [a]	*linear average* [a]
Former Soviet Union	Former Soviet Union	El Salvador
Turkey	Turkey	*Costa Rica*
Rest of Middle East	*linear average* [a]	*linear average* [b]
Morocco	Morocco	Morocco
Rest of North Africa	*linear average* [a]	*Tunisia*
South African Customs Union	*linear average* [a]	*Botswana*
Rest of Southern Africa	*linear average* [a]	*Zambia*
Rest of Sub-Saharan Africa	*linear average* [a]	*linear average* [a]
Rest of the World	*linear average* [b]	*linear average* [b]

[a] Linear average of income elasticity estimates for all or a subset of the countries comprising the region.

[b] Linear average of income elasticity estimates for representative countries, *i.e.* countries with 1995 GDP per capita similar to the 1995 per capita GDP of the individual countries comprising the region.