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Taking IMPACT Abroad: The Global Trade Analysis Project*

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Introduction

The Global Trade Analysis Project (GTAP) was established in 1992, and is based on the institutional principles of the IMPACT Project as described in Powell and Snape (1992). The overriding goal of GTAP is to lower the cost of entry for those seeking to conduct quantitative analyses of international economic issues in an economy-wide framework. The Project consists of several components:

* a fully documented, publicly available, global data base,
* a standard modeling framework,
* software for manipulating the data and implementing the standard model, and, most importantly,
* a global network of researchers (currently about 45) with a common interest multiregion trade analysis and related issues.

In addition, the Global Trade Analysis Consortium has recently been established to provide leadership and a base level of support to GTAP operations. When complete, this Consortium will consist of eight member agencies, each with a representative on the GTAP advisory board.

The GTAP data base builds on the 15 region, 37 sector, SALTER-III data base, developed at the Australian Industry Commission (Jomini, *et al.*). Under the auspices of several cooperative research agreements between Purdue University and USDA, the bilateral trade, transport, and protection data have been updated and improved. With the cooperation of members of the GTAP network, as well as support from the World Bank and USDA, GTAP regional coverage has been extended to 18 countries and 6 composite regions which together exhaust global economic activity. A complete listing of the disaggregated sectors and regions in the 1994 release of the GTAP data base is provided in table 1. (It should be noted that the application discussed in this paper is based on a modified version of the 1993 release. The 1994 release will be publicly available on July 15, 1994.)

In order to operationalize this large data base, a standard modeling framework has been developed using the GEMPACK software suite (Harrison and Pearson). This permits users to conduct simulations in which changes in policy, technology, population, and factor endowments are examined. In addition to these shocks, the user specifies the split between exogenous and endogenous variables (i.e. model closure). Under standard closure, the GTAP model is a conventional applied general equilibrium model. However, the presence of special slack variables also facilitates the implementation of partial equilibrium closures. Model outputs include a complete matrix of bilateral trade flows, activity levels and derived demands by sector and region, private and government consumption, regional welfare, and relative prices.

Following the example established by the IMPACT Project twenty years ago, an annual short course was established to introduce users to the data base and model structure in an efficient manner. This is offered each summer on the campus of Purdue University. For others who wish to familiarize themselves with the standard model structure, it will be available, along with several aggregations of the data base, on Purdue University's anonymous FTP site in August of 1994. There are currently about two dozen applications of the GTAP framework underway, worldwide. These are aimed at addressing a great variety of issues including: trade policy reform, regional integration, global climate change, and historical analysis of economic growth and trade.

This paper illustrates the value of the GTAP framework for trade policy work by providing discussing a contemporary application designed to evaluate the recently concluded GATT Agreement. Emphasis is placed on changes patterns of bilateral trade and employment, although the model may be used to examine impacts on production levels and regional welfare as well. This project was developed in conjunction with the US International Trade Commission and the US Trade Representative's Office. It is unique in the amount of specific policy information incorporated, and the level of sectoral detail offered. Unlike earlier analyses of the this trade agreement, all of which were based on highly stylized scenarios, this analysis is based on the actual offers made by individual countries. In addition to analyzing tariff cuts, the model is used to evaluate reductions in non-tariff barriers in the agriculture, textiles, and wearing apparel sectors. The former involves primarily commitments to increased market access via expanding quotas, as well as reductions in subsidized exports. The latter involves elimination of the Multifibre Agreement (MFA). This agreement restricts exports of textile products into North American and European markets, with the rents accruing largely to the exporters.

Overview of the Data Base

Figure 1 provides an overview of a slice of the GTAP data base. (For more details on the GTAP data base and model structure, see Hertel and Tsigas, 1994). This flowchart portrays the sources of sectoral receipts in the global data base. (In the model, all sectors are assumed to produce a single output. Therefore there is a one-to-one relationship between producing sectors and commodities.) At the top of the figure, *VOA(i,r)* refers to the *Value of Output at Agents' prices*, i.e. payments received by the firms in industry i of region r. These payments must be precisely exhausted on costs (not shown in figure), under the zero pure profits assumption.

If one adds back the producer tax (or deducts the subsidy) denoted by *PTAX(i,r)*, then we arrive at the *Value of Output at Market prices, VOM(i,r)*. This may be seen to be the sum of the *Value of Domestic sales at Market prices, VDM(i,r)* and the *Value of eXports of i evaluated at domestic Market prices in r, by Destination s, VXMD(i,r,s)*. In addition, we must take account of possible sales to the international transport sector, denoted *VST(i,r)*. These sales are designed to cover the international transport margins. (In this particular data base, only trade, transport and insurance services sectors have a non-zero entry for this flow.) Both *VST(i,r)* and *VDM(i,r)* are evaluated at market prices and face no border taxes.

In order to convert exports to *fob* values, it is necessary to add the destination-specific export tax, denoted *XTAXD(i,r,s)*. In fact, this discrepancy between the value of sales of commodity i from r to s, evaluated at market prices on the one hand, and world prices on the other, may also be induced by quantitative export restrictions. For example, in the 1994 GTAP data base, the system of bilateral export quotas on textiles and wearing apparel implemented under the Multifibre Arrangement, is treated as a set of bilateral export tax-equivalents. Therefore, the quota rents accrue to exporters. The same is true of export restraint agreements. In particular, the 1994 GTAP data base includes information from the GATT on the restrictiveness of price-undertakings by the European Union. Because these measures affect export destinations differentially, the bilateral detail is an important dimension of the GTAP data base.

Once the export taxes are added in, we obtain the *Value of eXports at World prices by Destination, VXWD(i,r,s)*. The difference between this and the *cif*-based *Value of Imports at World prices by Source, VIWS(i,r,s)*, is the international transportation margin: *VTWD(i,r,s) = the Value of Transportation at World prices by Destination* for commodity i, shipped from r to s. These bilateral trade and transport arrays are the centerpiece of the GTAP data base. They are estimated based on a 30 year time series of bilateral trade data available from the UN (Gehlhar, 1994). This estimation procedure takes advantage of the fact that each bilateral transaction is reported twice, once by the exporter and once by the importer. It uses estimated reporting biases, as well as bilateral, commodity-specific, *cif-fob* based transport margins, in order to reconcile these two observations. (All regional exports and imports are required to adjust to these reconciled flows in creating a globally consistent data base.)

At this point we have taken commodity i from its sector of origin in region r to the border of its export destination. In order to evaluate these sales at internal domestic prices in market s, it is necessary to add source-specific import taxes, *MTAXS(i,r,s)* to the *cif* values. As was the case on the export side, depending on the commodity and route, these revenues may correspond to actual taxes (eg., tariffs) or they may be rents associated with non-tariff barriers (eg., quotas). In the 1994 data base, MTAX(i,r,s) comprises *applied* tariffs, antidumping duties and rents associated with non-tariff

barriers in food and agricultural trade. The applied tariffs are obtained by aggregating detailed tariff schedules obtained from the GATT (Gray). By trade-weighting the individual tariff lines, prior to aggregation, we are able to capture the compositional flavor of the disaggregated data. For example, if developing countries tend to export a disproportionate share of heavily protected products to the US, then their bilateral tariff rates will be higher than average. Antidumping duties are explicitly bilateral in nature and are also obtained from the GATT for the US, Canada and the European Union. Non-tariff barriers for farm and food products are based on estimates by the OECD and ERS/USDA (McDonald, 1993).

After accounting for importer border distortions, we obtain *VIMS(i,r,s)*, the *Value of Imports at Market prices by Source.* These imports from alternative sources may then be combined into a single composite, *VIM(i,s)*, the *value of Imports of i into s at Market prices.* Just as sales in the r^{th} market had to be distributed across various destinations, so composite imports of i into s must be distributed across sectors and households in the s^{th} market.* Possible uses of imports include: *VIPM(i,s)* -- the *Value of Imports by Private households, evaluated at Market prices, VIGM(i,s)* -- *Value of Imports by the Government, evaluated at Market prices,* and *VIFM(i,j,s)* -- the *Value of Imports by Firms in industry j, at Market price.*

The allocation of imports and domestic goods across uses in each of the regional economies is based on the individual region input-output tables (eg., see Hambley). This feature of the GTAP data base, which was inherited from the SALTER effort, has proven extremely valuable in conducting analyses of trade liberalization. Because the intensity of imports may vary considerably across uses, a tariff cut will have a relatively more beneficial effect on those sectors of the economy which use the imported variant of this commodity more heavily. Conversely, those sectors/households using relatively little of the imported variants of a protected product will benefit less from the tariff cut. Unfortunately, not all countries distinguish between the sourcing of imported and domestic inputs. In these cases it is assumed that the pattern of usage is identical across sectors and households.

On the production side, the remainder of the data base describes primary factor demands by firms, commodity taxes, and finally, derived demands by firms at market and agent's prices. As noted above, the value of these purchases must precisely offset the value of firms' revenues at agent's prices, by virtue of zero profits. Households also face commodity taxes, and the combined expenditures of public and private households, coupled with savings demands, must exhaust regional income. The latter is derived from primary factor payments and tax revenues, net of subsidies. Finally, the value of exports to the international transport sector must be sufficient to cover the margins provided by the sector on international merchandise trade. Walras' Law implies that if all of the above accounting relations are satisfied, global savings equals global investment. This is the consistency check used in the GTAP framework.

*In the 1993 release of this model, imports were sourced by individual agents in the economy. Unfortunately, such a detailed breakdown of import sourcing is unavailable and this feature has been dropped in the interest of computational efficiency.

Overview of the Model Structure

With a few notable exceptions, the theoretical structure of the GTAP model follows that of any standard, multiregion applied general equilibrium model based on constant returns to scale/perfect competition. It purposely lags current developments in the AGE literature, in order to provide users with a robust tool for policy analysis. Many users (the present author included) will choose to incorporate "non-standard" features such as imperfect competition. This may be done by taking the GTAP data base as a starting point and augmenting it with information such as the number of firms in each industry/region and the nature of strategic interactions among these firms. The advantage of this incremental approach is that researchers can focus their attention squarely on the issues of greatest importance for their individual project, avoiding those burdensome data tasks which are common to all multiregion, AGE analyses.

Production Structure

Figure 2 provides a visual display of the assumed technology for firms in each of the industries in the standard GTAP model. This kind of a production "tree" is a convenient way of representing separable, constant returns-to-scale technologies. At the bottom of the inverted tree are the individual inputs demanded by the firm. For example, the primary factors of production are: land, labor and capital. Their quantities are denoted *qfe(i,j,s)*.

The manner in which the firm combines individual inputs to produce its output, *qo(i,s)*, depends importantly on the assumptions which we make about *separability* in production. In the GTAP model, it is assumed that firms choose their optimal mix of primary factors *independently* of the prices of intermediate inputs. Therefore the substitution elasticity between any primary factor and intermediate inputs is constant (and equal to zero). Within the primary factor branch of the production tree, substitution possibilities are also restricted to one parameter. This *constant elasticity of substitution* (CES) assumption is quite general in those sectors which employ only two inputs: capital and labor. However, in agriculture, where a third input, land, enters the production function, we are forced to assume that all pair-wise elasticities of substitution are equal. This is surely not true, but we do not have enough information to calibrate a more general specification at this point.

Firms also purchase intermediate inputs. Domestic inputs *qfd(i,j,s)*, are sourced separately from the imported inputs, *qfm(i,j,s)*. In the case of imports, the intermediate inputs must be "sourced" from particular exporters. As noted in figure 1, this sourcing occurs at the border since information on the composition of imports by sector is unavailable. Therefore *qfm(i,j,s)* is really a composite of exports from different sources, *qxs(i,r,s)*. Finally, composite intermediate inputs and value-added are assumed to be combined in fixed proportions.

Household Behavior

In the standard GTAP framework, all final demand and savings within each region is conceptualized as emanating from a single "super-household" (see figure 3). This household disposes of total regional income according to a Cobb Douglas per capita utility function specified over the three forms of final demand: private household expenditures, government expenditures and savings. Thus in the standard closure, the claims of each of these uses represents a constant share of total income. Alternatively, the user may specify the level of government spending, and/or savings exogenously, with residual income being spent on private household consumption.

Once real government spending has been determined, the next task is to allocate this spending across composite goods. Here, the Cobb Douglas assumption of constant budget shares is once again applied. This means that the share of total regional income spent on composite commodities by the government sector is constant, under standard closure assumptions. The remainder of the government's utility "tree" is completely analogous to that of the firms represented in figure 1. First, a price index is established, then composite demand is allocated between composite imports and domestically produced goods. Due to the lack of use-specific Armington substitution parameters, σ_D is assumed to be equal across all uses, i.e. across all firms and households. Therefore, the only thing that distinguishes firms' and households' conditional import demands are the differing import shares.

Treatment of private household demands is one of the areas in which the GTAP framework differs from standard AGE models. In particular, it employs the CDE functional form, first proposed by Hanoch. The CDE lies midway between the nonhomothetic CES on the one hand, and the fully flexible functional forms on the other. Its main virtue is the ease with which it may be calibrated to existing information on income and own-price elasticities of demand for composite commodities. (For an exhaustive treatment of the calibration and use of the CDE functional form in AGE models, see Hertel *et al.*, 1991.) Like the government household, the allocation of composite demands across imports and domestic goods follows the approach outlined in figure 1.

Global Sectors

A global banking sector intermediates between regional savings and investment in the model. Households demand a homogeneous savings commodity, the price of which represents a composite of regional investment goods prices. Depending on the assumed closure, the allocation of the global investment portfolio among regional economies may be sensitive to the expected rate of return. Here, the model follows the approach employed in the comparative static, ORANI model for the allocation of investment across *sectors* in that single region model (Dixon *et al.).*

The global transport sector absorbs exports of trade and transport services from the individual regional economies and supplies the value-added between *fob* exports and *cif* imports of a given commodity along a particular route. The transportation technology is one of fixed proportions. However, input augmenting technical change is also possible in this portion of the global economy.

Partial Equilibrium Closures

One of the most popular aspects of the GTAP modeling framework is the ease with which partial equilibrium closures may be implemented. Newcomers to applied general equilibrium analysis are invariably interested in contrasting PE and GE results. Such comparisons greatly facilitate teaching users the basic mechanisms at work in the model. Experienced users, on the other hand, value these closures because they assist in decomposing the sources of GE changes into several parts. For example, in examining the link between trade and growth, one might wish to examine how much of the change in trade is due to the changing incomes, and how much is due to changing endowments. Both of these groups of users are well-served by the presence of slack variables in key equilibrium conditions in the model. When endogenized, these variables effectively eliminate that equation from the model, and permit the user to fix the associated complementary variable. By way of example, one might choose to fix the price of a tradeable commodity, while simultaneously eliminating the associated market clearing condition.

A common partial equilibrium closure for the analysis of farm and food issues involves fixing the prices of all nonfood commodities. In order to implement this closure in the GTAP model, all nonfood market clearing conditions must be "dropped" by endogenizing slack variables in the equations to be eliminated. It is also common to assume that the opportunity cost of non-specific agricultural factors is exogenous. If this is to be done, then the associated regional market clearing conditions for these non-tradeable primary factors must be dropped. Similarly income is often fixed in partial equilibrium analysis, in which case the income computation equation must be eliminated.

But what about quantities? Should any of them be fixed? Having fixed the price of (eg.) nonfood commodities, it hardly makes sense to permit their supplies to be determined endogenously. One could envision a sector experiencing a rise in costs being driven out of business altogether under such circumstances. For this reason it makes sense to fix nonfood output levels and drop the associated zero profit conditions.

To summarize, if one chose to conduct a partial equilibrium analysis of food policy, for example, one possible set of closure assumptions may be summarized as follows:

- *nonfood output levels and prices are exogenous*
- *income is exogenous*
- *nonland primary factor rental rates are exogenous.*

Finally, it is also possible to conduct single region GE/PE analyses, by exogenizing appropriate variables in the rest of the world. This permits a contrast between single and multi-region results.

Model Implementation

The model is implemented using the GEMPACK suite of software (Harrison and Pearson, Pearson). This has a number of very attractive features from the point of view of GTAP. The most important of these is the ability to *condense* the model down to a manageable size. This is essential since multiregion, applied GE models with differentiated products grow very rapidly as the number of regions and commodities increases. For example, in the disaggregated GTAP data base, there are 37 x 24 x 24 = 21,312 bilateral flows -- yet this is only one variable in the model! For this reason, virtually all applications are undertaken at a substantial level of aggregation. Even so, it is common for the numerical model to contain 50,000 equations. Consequently, we utilize GEMPACK to substitute out most of the large dimensional variables, solving instead for the primitive variables, such as prices, activity levels and utility. (Provided one indicates this need in advance, the values of these variables may be readily retrieved in the final solution.) In this way it is possible to conduct disaggreated analyses with GTAP in a PC environment.

An Illustrative Application

Preliminary Observations

For purposes of illustration, I have chosen to pull material from a contemporary application of the model to analyze the Uruguay Round, multilateral trade agreement reached under the auspices of the GATT. While there is not room here for an exhaustive analysis of this application, I believe that a

discussion of its implementation and a few results, will be informative for the reader interested in obtaining a feel for the model.

Apart from the topical nature of this application, the GATT experiment is of interest because it is precisely the type of problem which GTAP is best-suited to address. First of all, consider the issue of sectoral and regional coverage. The GATT agreement potentially affects all sectors of almost all economies worldwide. Therefore, in order to implement the full experiment it is necessary to use a global, economywide model. Secondly, since most of the measures in this agreement are trade-related, and some are explicitly bilateral (eg., the Multifibre Arrangement) a model and data base which place special emphasis on bilateral trade patterns and protection is important for the analysis.

In keeping with the comparative static nature of the standard GTAP model, this experiment simulates what the global economy would look like today, if the proposed cuts were implemented, and nothing else were changed. This has several obvious drawbacks. First of all, since the cuts are phased in over a period of 5 - 10 years, comparative static analysis is unable to capture the timing and sequence of reforms. Actual reductions in protection are likely to be more gradual than that represented in the simulations below. Indeed, in many industries the amount of adjustment required due to *other* exogenous shocks is likely to dwarf the changes reported here. Unfortunately, our ability to trace the actual development of the global economy over the next 10 years is very limited. This makes it difficult to establish a baseline for purposes of comparison with the GATT scenario. Furthermore, there is substantial uncertainty about the timing and sequence of the GATT cuts in protection. Therefore, the dynamic path of the counterfactual experiment is also unclear. For this reason, I believe that construction of a reliable comparative static, GATT experiment is a good starting point.

A second drawback of comparative static analysis relates to its inability to capture the effects of trade reform on capital accumulation and economic growth. Endowments and technology remain constant throughout the course of the experiment. To the extent that trade reform encourages more rapid rates of investment and innovation, the results reported here will understate the true gains from trade reform. There have recently been some advances in applied general equilibrium modeling which permit one to capture some of these dynamic effects. No doubt this type of work will become routine in a few years time. However, at present this type of analysis requires sacrificing sectoral and regional detail in the model. Therefore, it must be viewed as *complementary* to this type of disaggregate, comparative static analysis.

Experimental Design

Agricultural Reforms: Table 2 summarizes the major features of the Uruguay Round simulation. Agriculture is probably the most complicated part of the agreement and I will begin the discussion here. In this area there are four major types of shocks: cuts in subsidized exports, quantitative market access commitments, cuts in tariff and tariff-equivalent non-tariff barriers to trade, and cuts in domestic subsidies. They are referred to collectively as the *AGR* experiment below. Each component of *AGR* will now be discussed, in turn.

The Uruguay Round Agreement specifies both a quantity and a value reduction in subsidized exports on a product-specific basis. I have chosen to focus on the reduction in subsidized export quantities, which is 21%. In order to achieve precisely this reduction in exports, I alter the standard GTAP closure, in which aggregate exports are endogenous and the *ad valorem* equivalent of the

border policy is exogenous. In the new closure, the volume of exports is exogenous and the subsidy is endogenous. Thus the model predicts the reduction in subsidy levels necessary to achieve the required reduction in subsidized exports. This policy reform was aimed at the European Union, where the bulk of exports for a number agricultural commodities are subsidized (see table 2 for details).

A second important area of the GATT agreement in agriculture has to do with minimum access commitments for agricultural products. Under these commitments, individual countries agree to particular quantitative targets for imports, expresses as a percentage of domestic use. In the experiment conducted below, minimum access shocks are implemented by making aggregate import volumes exogenous and endogenizing the import tariff-equivalent. Imports are then shocked by an amount sufficient to achieve the prespecified target. Minimum access shocks are applied to rice, wheat, coarse grains, meats and milk products in the countries identified in table 2. In most cases, the increases are sufficient to achieve the 5% goal specified in the agreement. However, in the case of rice in Korea and Indonesia a somewhat lower target (4%) is applied. Finally, in the case of Japan, where an 8% goal has been agreed to, the shock was infeasible due to the very limited amount of initial imports in the data set. Instead, the import barrier is simply removed.

Cuts in tariffs and non-tariff equivalents on agricultural imports are also part of the experiment. In the industrialized economies, these barriers are required to be cut by 36%, on a simple average basis, with a 15% minimum cut. In the developing economies, the cuts are only two-thirds as deep (24% and 10% respectively). There are several reasons to believe that the actual cuts in these border measures will be more modest than implied by the simple averages.** Therefore, I have chosen to implement these cuts at the lower end, i.e. 15% reductions in tariff and non-tariff barriers in agriculture.***

Non-agricultural Tariff Cuts: The simplest, and most accurate part of the GATT simulation exercise, is that which pertains to non-agricultural tariff cuts. All tariffs in the GTAP data base used for this study are obtained from the country tapes submitted to the GATT under the Uruguay Round. Here, I use the *applied tariff rates* as the starting point for these simulations. These are aggregated up from the individual tariff lines, weighting the rates by import levels. Thus the aggregated, trade-weighted tariffs vary bilaterally, and reflect differences in composition across trade routes. Rather than cutting these tariffs via a predetermined formula, they are instead cut by the amount necessary to generate the revised tariff levels obtained by aggregating the individual country offers submitted under the GATT Round. In other words, this part of the experiment is wholly *data-based.*

** First of all, there is tremendous variation in tariff rates on farm and food products. Cuts in a few of the very high tariffs on minor products can lower the simple average rate considerably without markedly affecting the trade-weighed tariff. A second reason why the formula cuts may be overly optimistic about trade creation in agriculture stems from the wide latitude available in developing tariff-equivalent measures of existing NTBs. By appropriate choice of base period prices, etc., countries can inflate their estimated tariff equivalent for sensitive products. In this way, they can avoid significant cuts in protection, even after the minimum 15% cut is implemented. Indeed there is considerable evidence that countries are pursuing this strategy.

*** Yet another area of the agreement on agriculture which lends itself to quantification is the reduction in internal support. Here countries are to cut their *total* aggregate measure of support during the 1986-88 period by 20%. It is important to note that world prices were extraordinarily low in this base period, and have subsequently risen for most commodities. This, combined with the fact that the AMS cut is for the sector *as a whole*, means that this cut has already been "achieved". I.e. no further cuts are required to come into compliance with the GATT. For this reason reductions in internal support are not part of the experiment reported here. This doesn't mean that the internal support provisions are unimportant. It is likely that they will become binding again in the future, particularly for those countries which do not achieve meaningful reform of their domestic farm policies. However, for purposes of this comparative static simulation, these reforms are not relevant

It should be noted that the depth of these cuts in non-food tariffs is largest in the wealthy countries, where the initial level of tariffs is already very low. The depth of cuts in the developing countries, where tariffs are still quite high, is much more modest. Indeed, in some of the developing countries, where current tariffs are not bound, tariff offers exceed the applied rates. This does not mean that these countries will raise their tariffs as a result of the Uruguay Round, however, it does mean that the agreement does not impose current reductions in tariffs in many countries where current manufacturing protection levels are still quite high. These cuts in non-food tariffs are combined with the agricultural shocks to result in the *CUTS* scenario in the subsequent tables.

Multifibre Arrangement

Outside of agriculture, the most distorted part of the world economy pertains to trade in textiles and wearing apparel. Here, the Multifibre Arrangement (MFA) has prevented the production of labor intensive commodities from shifting naturally from high wage to low wage regions. Bilateral quotas facing exports into the US, Canada and Europe have not only served to retain excess capacity in this industry domestically, they have also distorted the pattern of sourcing for the products which come in under the quotas. Estimates of the bilateral export tax-equivalent values of these quotas are available from a number of sources. The estimates used in this study are based on a study by the Australian Industry Commission, based in part on the work of Yongzheng Yang (Gotch 1993). These estimates were updated to the present, based on personal communication with Dr. Yang.

The Uruguay Round Agreement calls for a phasing out of the MFA. The period for implementing this is 10 years, which is twice the normal implementation period under the GATT. In the meantime there are a number of safeguards which will serve to delay adjustment until late in this phase-in period. Because of this delayed implementation, the simulations reported below include elimination of the MFA as a final experiment, labeled *GATT*, conducted in addition to the other measures. In other words, *GATT* = *CUTS* + *MFA*.

Results

The GTAP model, and other AGE models of this sort, are particularly good at assessing the *relative* impact of trade policy reform on output, price and employment in different sectors in the economy. Also, by incorporating detailed information on current patterns of bilateral trade, transport costs and protection, GTAP is well-suited to analyzing changes in the pattern of trade which might result from the trade agreement. In the GTAP aggregation employed for this study, there are 25 sectors. Half of these relate to food, textiles and wearing apparel, in keeping with the emphasis on these products in the current GATT round.

In order to limit the bilateral detail in the simulation results, the data base is aggregated up to six regions: USA, Canada, European Union, Japan, (other) Pacific Asia, and the Rest of World. The US, EU and Japan are the largest markets. They also have significant barriers to trade in agricultural products. The US, EU, and Canada also have major trade barriers in the area of textiles and wearing apparel. Pacific Asia is an area that faces stiff export restraints, particularly in textiles and wearing apparel. It is also emerging as an important growth market, and it is well-represented in the GTAP data base.

Impact on Total Trade Volume: Table 3 reports the changes in total merchandise trade *volume* (measured in base period, US dollars), on a bilateral basis, as a result of the full GATT experiment.

The rows in this table refer to *sources* of trade flows, i.e. exporters, while the columns refer to *destinations* i.e., importers. Summing across all destinations gives the total increase in trade volume, in 1990 US dollars. Thus US exports are projected to rise by $23,823 million, while Canadian exports increase by $5,265 million as a result of the *GATT* scenario outlined in table 2. For purposes of comparison, the change in total trade volume due to the *CUTS* and *AGR* scenarios are also provided in the margin of this table. Differencing *GATT* and *CUTS* shows that about $36 billion of this world total is due to reform of the MFA. Comparison of *AGR* and *GATT* indicates that the agricultural reforms outlined in table 2 generate about 10% of the $119 billion increase in total trade volume.

Inspection of the column totals in table 3 indicates that the largest increase in import volume occurs in the EU, where it increases by about $36 billion. USA is second, with an increase of $28 billion, followed by Pacific Asia, ROW, and finally, Japan and Canada. It is rather striking that the increases in trade volume for Japan are not much larger than those for Canada. In contrast, Pacific Asia plays a very important role, rivaling EU in the total increase in export volume. This is followed by USA, ROW, and then Japan and Canada.

The figures in table 3 also highlight several bilateral trade relationships which deserve attention. Despite the overall predominance of EU in increased world imports, it is Pacific Asia which is the most important destination for USA exports under the *GATT* scenario. More than one-third of the $23.8 billion increase in export volume goes to PAS. This increase is complemented by an increase in USA imports from PAS of $12.8 billion -- or almost half of the total increase in import volume by USA under *GATT*.

Table 3 also highlights the close bilateral link between EU and the non-Asian, non-North American markets which are aggregated into ROW. Indeed almost all of the increase in ROW imports is supplied by EU. On the import side, ROW is rivaled by PAS as a supplier of increased exports to the EU market under *GATT*. This is followed by USA which increases export volume to the EU market by $6.8 billion.

Impact of GATT on Bilateral Trade in Textiles and Wearing Apparel: Table 4 reports the bilateral changes in volume of textiles and wearing apparel under the GATT scenario. Again, rows correspond to exporters and columns to importers. Note from the column totals that imports increase in all regions of the world, not just in the restricted importing regions (USA, CAN, EU). Worldwide trade in textiles and wearing apparel increases by $46.7 billion, with $34 billion of this due to increased imports in USA and EU. On the export side, all regions, with the exception of Canada, increase their sales of textile and wearing apparel products overseas. The majority of this increase comes in PAS, where exports rise by $30 billion. This is followed by ROW where the increase is $13.8 billion.

Turning to the interior elements of table 4, we notice some interesting changes in the composition of trade. Elimination of the MFA alters the sourcing of imports by the previously restricted countries in favor of PAS and ROW. Despite the aggregate increase in imports by USA, CAN and EU, sales from the wealthy countries actually decline. However, sales by these countries to other regions rise. For example, US exports of textile and wearing apparel products to PAS rise by $761 million. How can this occur? There is currently a significant amount of *intra-industry* trade in which designs and specialty products are exported from the USA to PAS, and later imported in the form of finished products. In order to supply the US market with additional clothing, more of these

high-value, intermediate goods are needed by the textile and wearing apparel industries in Pacific Asia.

Impact on Trade in Farm and Food Products: Table 5 reports the bilateral changes in volume of trade for food and agricultural products as a result of *GATT*. Once again, rows refer to exporters and columns refer to importers. It is interesting to note that the $11 billion increase in trade volume is quite similar to the *AGR* total in table 3. That is, the impact of food and agricultural trade reform on *total* trade volume is roughly equal to the impact of the total trade reform package on *farm and food* trade volumes.

As in table 3, EU is the predominant destination for increased exports, with the majority of these coming from ROW. However, unlike the changes in total export volumes reported in table 3, EU exports of food and agricultural products actually fall. The biggest decrease in volume arises in ROW. This is because of the provision reducing subsidized food exports. Of course not all EU food exports are subsidized, and table 5 reports an increase in exports to USA and Canada.

Examination of the first row in table 5 shows that almost one-third of the $3.6 billion increase in US food exports goes to Pacific Asia. As was the case with total trade volumes, the US experiences disproportionate gains in the PAS region. This is followed by EU, ROW and then Japan. Meanwhile, the largest increase in PAS exports consists of intra-regional sales. This region contains important food importers, such as South Korea and China, as well as exporters such as Thailand and Australia. Therefore, it is not surprising that when member countries reform their policies (the disaggregated data base contains data on individual countries and their trade policies), intra-regional trade increases.

Impact on Employment in the United States: One of the major areas of concern for individual nations negotiating a multilateral trade agreement is the impact on employment opportunities. It is usually fairly evident where jobs will be lost -- namely in the most heavily protected sectors. However, it is less clear where new jobs will be created. As demonstrated by the IMPACT Project's contribution to the debate over tariff reform in Australia, identifying where new employment opportunities may arise is one of the most useful features of applied general equilibrium analysis (eg., Dixon, 1993).

The GTAP data base contains information on payments to labor in each sector of each region. When shocked, the model decomposes the change in sectoral payments to labor into a price and quantity component. If one assumes an average wage rate (I have taken $30,000/year in the case of USA), then the quantity changes can be translated into changes in the number of employees per sector (each row corresponds to a sector). These are reported in table 6 for the case of the US economy. To the extent that this average annual wage *overstates the average wage* of workers released (hired) from a given sector, the figures in table 6 will be an *understatement of the number of workers* released (hired). The opposite also applies. Higher than average wage sectors will have their job turnover overstated in table 6.

The first thing to note from table 6 is the fact that all of the column sums are equal to zero. This is a result of the assumption in the GTAP model that aggregate employment does not change. An alternative assumption, sometimes employed in AGE models is to fix the real wage and permit labor supply to adjust. A few models incorporate a more sophisticated representation of the labor market, however, this is a difficult and controversial area for AGE modelers. The advantage of the

fixed employment assumption is that it highlights the role of intersectoral competition for scarce resources.

Once again the three columns in table 6 refer to the three experiments discussed in table 2. In the US, global agricultural liberalization tends to draw resources into the farm sector. Processed food production actually declines, as the increases in processed meats and rice are outweighed by reductions in milk products, other processed food and beverages and tobacco. Since the farm sector is relatively capital intensive, its expansion bids up the relative cost of capital and sectors are encouraged to substitute labor for scarce capital. Many of the non-food sectors contract in order to make capital available to the expanding sectors. Meanwhile, the small percentage adjustment in the wage-rental ratio results in the labor intensive, traded service sector expanding slightly and thereby absorbing the "excess" labor.

The second column in table 6 describes the sectoral reallocation of labor when non-food tariff offers are also implemented. This further encourages expansion of the natural resource-based industries, while resulting in a stronger contraction of output and employment in textiles, wearing apparel, leather, chemicals, iron and steel and other manufacturing.

The final column of table 6 reports the full *GATT* scenario, whereby the MFA is also eliminated. This has a striking effect on the pattern of job losses in the US economy. Rather than being spread across a wide range of manufacturing activities, they are now concentrated in a few industries -- primarily textiles and wearing apparel. Since the average wage in wearing apparel is well-below $30,000, adjustment required by the model is more than the 220,000 jobs shown in table 6. In light of this result, it is hardly a surprise that this industry is being given twice the normal adjustment period, and the phase-in is coupled with safeguard measures.

Summary and Conclusions

In summary, this paper has documented progress to-date in an effort to "take IMPACT abroad" through the Global Trade Analysis Project. In proceeding with this effort, GTAP has attempted to adhere to the advice provided by Alan Powell, long-time Director of the IMPACT Project. This is nicely summarized in the following excerpt from Powell and Snape (1992, pp 14-15):

> The experience of Impact suggests that such a modelling exercise:
>
> 1. should not be run entirely within a university, nor entirely within the client policy agencies;
> 2. should be accompanied by full public documentation of data, methods, and results;
> 3. should have detailed involvement of the policy clientele in the design stage of model building;
> 4. should be at full arm;s length from executive government.
>
> The last of these recommendations involves putting some space between the practitioner who is crafting the policy advice. The credibility of the tools should not be left too vulnerable to misjudgments by policy analysts or to the political popularity of particular policy recommendations based

on them. Item 3 above, on the other hand, emphasizes that a policy-oriented model will be of limited use if no policy adviser uses it with enthusiasm. Item 2 is simply a criterion for scientific work: results must be capable of replication. Where conflicting interests are at stake, it is unreasonable to expect opponents to accept the reasonableness of assumptions or the internal consistency of simulations without full documentation; moreover, they can be relied upon to invest considerable resources into unearthing any shoddy work. And in any event, abiding by best scientific practice is the assurance of quality control. Item 1 recognizes complementarities between the discipline of a civil service environment, which encourages working to a pre-announced research program, and the creativity of the academic environment, which often does not.

In an effort to follow this sage advice, several steps are being taken. First, a book documenting the GTAP modeling framework and featuring eight, diverse applications, is currently under preparation. This, together with the detailed course notebook compiled each year, will provide exhaustive documentation of the annually released data base and modeling framework. (As noted above, the data is available, at cost, in either aggregated, or fully disaggregated form. Interested individuals should contact the author.)

At last count, there were about 50 members of the GTAP network, in 15 different countries. This network is expected to double in size over the next year. These individuals represent a diverse group comprising academics, government researchers, policy analysts, policy advisors and private consultants. It is through these individuals that the GTAP framework is being brought to bear on issues of contemporary concern. For example, analyses of the GATT agreement using GTAP are currently being undertaken at the GATT itself, as well as the World Bank, the European Commission, and the US International Trade Commission. The success of GTAP in creating a policy clientele will hinge critically on the success of these types of internal applications.

In order to provide a base-level of support for GTAP, and provide some leadership -- while maintaining autonomy from the governmental bodies, a Consortium of national and international agencies has been established. Each of these members will be represented on the GTAP advisory board. This board will advise the Director on matters of policy, research agenda and funding. In so doing, they will help to set the direction of the GTAP data base and modeling framework. This will include issues such as further disaggregation of countries and commodities, frequency and distribution of data updates, policies for incorporating new information, software development and extensions of the standard modeling framework, and the design and location of future short courses. In this way it is hoped that GTAP will keep "on-track" so that it is well-placed to contribute to public debate on issues of global trade and resource use.

References

Dixon, P.B. (1993). "Applied General Equilibrium Modelling: Achievement, Failure and Potential", IMPACT Project General Paper No. G-106, Monash University.

Dixon, P.B., B.R. Paramenter, J. Sutton, and D.P. Vincent. Orani: A Multisectoral Model of the Australian Economy, North Holland Publishing, New York, NY, 1982.

Gehlhar, M. (1994). "Development and Reconciliation of Trade Data to Complement the Regional IO Tables for Use in GTAP," GTAP Short Course Documentation, Purdue University, 1994.

Gotch, M. (1993). "Industry Assistance for SALTER." SALTER working paper No. 14. Industry Commission, Canberra, Australia.

Gray, D. (1994). "Development of Bilateralized Tariffs for Use in GTAP", GTAP Short Course Documentation, Purdue University, 1994.

Hambley J., "Early Stage Processing of International Trade and Input-Output Data for SALTER". SALTER Working Paper No.15, 1992

Hanoch, G. 1975. "Production and Demand Models in Direct or Indirect Implicit Additivity," Econometrica, 43:395-419.

Harrison, J., and K.R. Pearson, K.R. (1994). GEMPACK 5.1 Documentation, The IMPACT Project, Monash University.

Hertel, T.W., E.B. Peterson, P.V. Preckel, Y. Surry and M.E. Tsigas (1991): "Implicit Additivity as a Strategy for Restricting the Parameter Space in CGE Models," Economic and Financial Computing 1(1):265-289.

Hertel, T.W. and M.E. Tsigas (1994). "Structure of the Standard GTAP Model", GTAP Short Course Documentation, Purdue University, 1994.

Jomini, P., J.F. Zeitsch, R. McDougall, A. Welsh, S. Brown, J. Hambley, and J. Kelly. 1991. SALTER: A General Equilibrium Model of the World Economy, Vol. 1, "Model Structure, Database and Parameters". Industry Commission: Canberra, Australia.

Pearson, K.R. (1991). "Solving Nonlinear Economic Models Accurately Via a Linear Representation: IMPACT Project Working Paper No. IP-55.

Powell, A.A. and R.H. Snape. (1992). "The Contributioon of Applied General Equilibrium Analysis to Policy Reform in Australia." Impact Project General Paper No. G-98, Monash University.

Figure 1. Distribution of Sales to Regional Markets

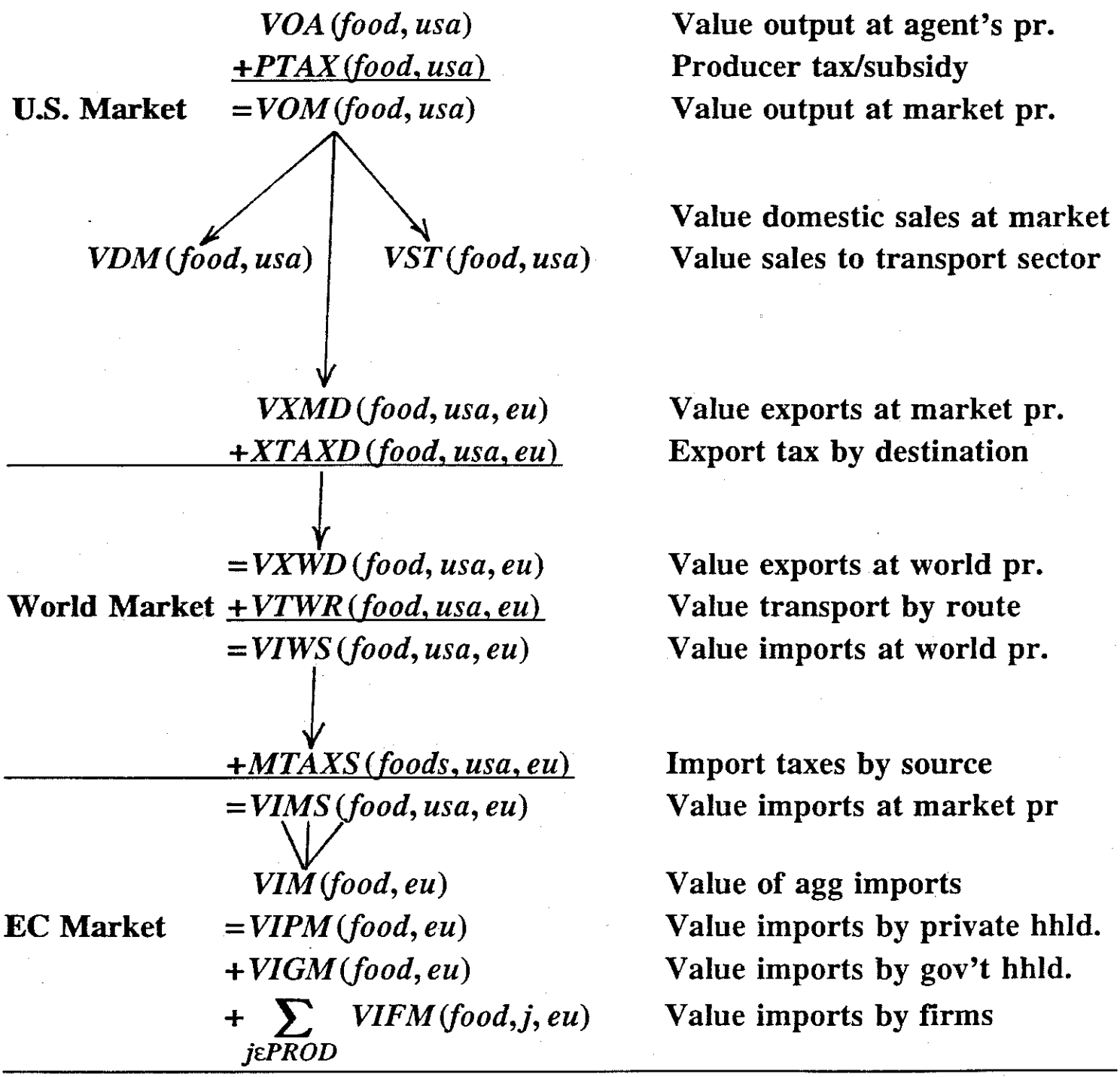
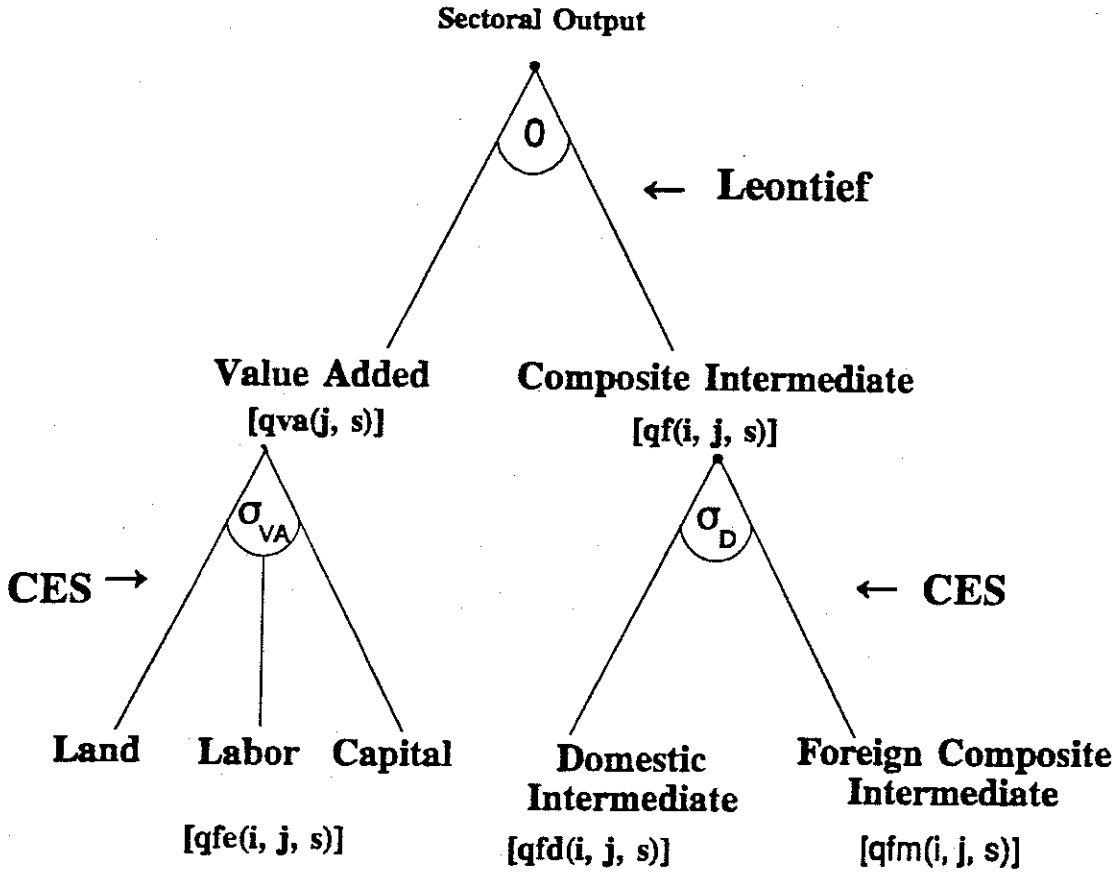


Figure 2. Production Structure in the Model



Import Sourcing at Border:

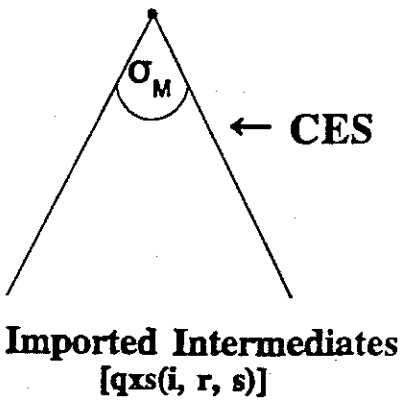


Figure 3. Household Utility Trees

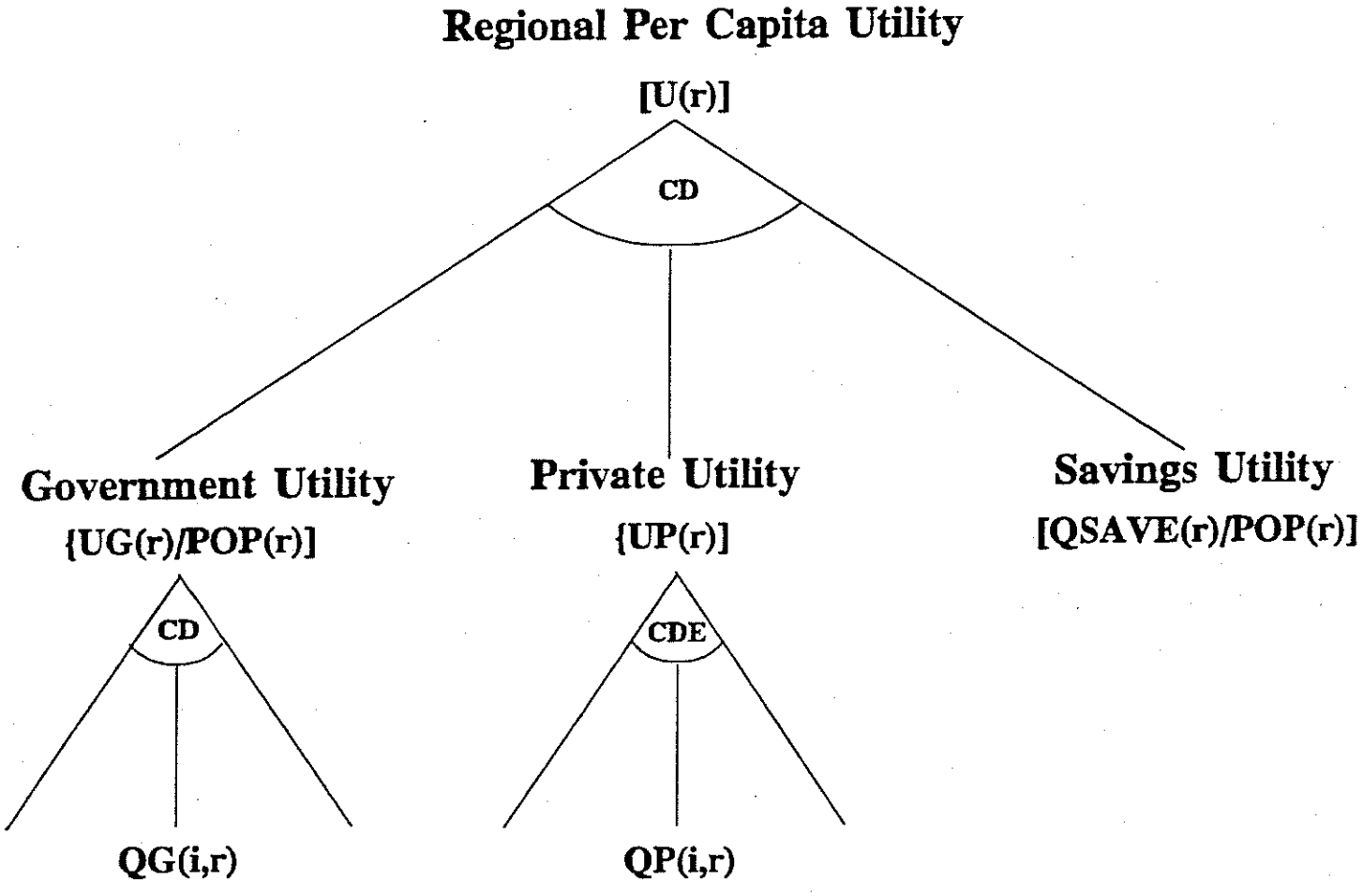


Table 1. The Disaggregated, 1994 GTAP Data Base

Listing of regions in the 1994 data base

1.Australia
2.New Zealand
3.Canada
4.United States of America
5.Japan
6.Republic of Korea
7.E.E.C.-12
8.Indonesia
9.Malaysia
10.Philippines
11.Singapore*
12.Thailand
13.People's Republic of China
14.Hong Kong
15.Taiwan
16.Argentina*
17.Brazil*
18.Mexico*
19.Rest of Latin America*
20.Sub-Saharan Africa*
21.Middle East and North Africa*
22.Eastern Europe and Former Soviet Union*
23.South Asia*
24.Regions not elsewhere classified.

* New addition in 1994.

Listing of industries

1. Paddy Rice
2. Wheat
3. Grains (other than rice and wheat)
4. Non-grain Crops
5. Wool

Listing of industries (Con't)

6. Other Livestock
7. Forestry
8. Fishing
9. Coal
10. Oil
11. Gas
12. Other Minerals
13. Processed Rice
14. Meat Products
15. Milk Products
16. Other Food Products
17. Beverages and Tobacco
18. Textiles
19. Wearing Apparel
20. Leather, etc.
21. Lumber and Wood
22. Pulp, Paper, etc.
23. Petroleum and Coal Products
24. Chemicals, Rubber, and Plastics
25. Non-metallic Mineral Products
26. Primary Ferrous Metals
27. Non-ferrous Metals
28. Fabricated Metal Products Nec
29. Transport Industries
30. Machinery and Equipment
31. Other Manufacturing
32. Electricity, Water and Gas
33. Construction
34. Trade and Transport
35. Other Services (private)
36. Other Services (government)
37. Ownership of Dwellings

TABLE 2. Elements of the Uruguay Experiment

AGR Experiment:

- Reductions in subsidized agricultural exports:

  Exogenous 21% cut in quantity of EU exports of rice, wheat, coarse grains, meats and milk. Export tax equivalent is endogenous (shrinks).

- Quantitative minimum access commitments for agriculture:

  Goal is 5% of domestic use. However, it is being handled on a "request/offer" basis. Implemented as exogenous increase in imports/endogenous tariff equivalent for:

  - rice in Japan, EU, Korea and Indonesia,
  - wheat in Japan and EU,
  - coarse grains in Japan and EU,
  - meats in EU, USA, Korea, Philippines and Thailand,
  - milk products in EU, USA, Canada, and Korea.

- Cuts in food and agricultural tariffs (applied rates) and tariff equivalents (1986-88 average) for NTBs:

  - 15% minimum in industrialized countries (36% simple average),
  - 10% minimum in developing countries (24% simple average).

CUTS = AGR Plus the Following:

- Non-agricultural tariff cuts: based on actual offers.

GATT = CUTS + MFA:

- Relaxation of bilateral quotas underpinning Multifibre Arrangement (MFA): Time frame for this is somewhat longer than other reforms.

TABLE 3. Impact of GATT on Total Trade: Change in Volume in $Million at 1990 Prices

SOURCE	*DESTINATION*						*TOTALS*		
	USA	*CAN*	*EU*	*JPN*	*PAS*	*ROW*	*GATT*	*CUTS*	*AGR*
USA	n.a.*	1907	6867	3098	8423	3528	23823	16023	1720
CAN	3400	n.a.	1143	278	373	71	5265	4135	186
EU	4107	590	n.a.	3040	6829	16190	30666	23126	3595
JPN	2490	591	1433	n.a.	1797	879	7191	7301	496
PAS	12860	2334	13382	1557	2250	-1776	30606	17492	2573
ROW	4985	268	13559	105	2699	-226	21389	14260	2454
GATT TOTAL	27753	5690	36383	8078	22372	18865	118941	n.a.	n.a.
CUTS TOTAL	16232	4108	24160	8446	15449	13941	n.a.	82339	n.a.
AGR TOTAL	1820	315	4269	854	2253	1516	n.a.	n.a.	11027

* Intraregional trade is not relevant for individual countries.

TABLE 4. Impact of GATT on Bilateral Trade in Textile and Wearing Apparel: Change in Volume in $Million at 1990 Prices

SOURCE	*DESTINATION*						
	USA	*CAN*	*EU*	*JPN*	*PAS*	*ROW*	*TOTAL*
USA	n.a.*	-285	-494	142	761	134	259
CAN	-232	n.a.	-25	2	52	5	-198
EU	-1186	-165	n.a.	754	682	2477	2561
JPN	-220	-17	-180	n.a.	986	88	657
PAS	12754	2336	11131	683	2984	-251	29638
ROW	5907	335	6431	30	1114	-13	13806
TOTALS	17022	2203	16861	1612	6582	440	46723

* Intraregional trade is not relevant for individual countries.

TABLE 5. Impact of GATT on Bilateral Trade in Food Products: Change in Volume in $Million at 1990 Prices

SOURCE	*DESTINATION*						
	USA	*CAN*	*EU*	*JPN*	*PAS*	*ROW*	*TOTAL*
USA	n.a.*	76	981	648	1074	881	3661
CAN	243	n.a.	338	73	54	128	838
EU	640	76	n.a.	-65	-28	-809	-186
JPN	32	4	35	n.a.	197	17	285
PAS	246	2	919	153	1218	27	2566
ROW	332	6	3113	111	396	-23	3935
TOTAL	1494	164	5387	920	2912	221	11098

* Intraregional trade is not relevant for individual countries.

TABLE 6. Impact of GATT on Sectoral Employment in the US (Change in Numbers of Jobs)

COMMODITY	*AGR*	*CUTS*	*GATT*
RICE	43	46	65
WHEAT	936	974	1151
C. GRAINS	750	788	1029
OTHER CROPS	1773	2218	4236
LIVESTOCK	1021	1101	1772
FOR/FISH	156	427	1701
FOSSIL FUEL	542	5646	10669
OTHER MINING	-15	-499	4995
MILLED RICE	136	142	179
MEAT PRODS	1031	989	1183
MILK PRODS	-1101	-1138	-1041
OTHER FOODS	-763	-914	371
BEV & TOBACCO	-628	-560	627
TEXTILES	-1703	-2915	-46325
APPAREL	-1151	-13337	-220839
LEATHER	-918	-3075	-844
WOOD PROS	66	-2829	4898
PETRO & COAL	694	927	-1119
CHEM/RUBB/PLAST	-420	-918	1305
IRON & STEEL	-482	-2034	5873
NONFERR METALS	-125	156	4019
VEHICLES	-3056	15738	41460
OTH MNFC	-3718	-19233	45826
TRADED SVCE	6944	26441	115226
NONTRADED SVCE	-10	-8143	23576
TOTAL	0	0	0