



*Adjusting Tax Rates in  
the GTAP Data Base*

**Gerard Malcolm \***

**GTAP Technical Paper No. 12**

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## *Abstract*

This paper describes a procedure designed for incorporating improved information on taxes into existing GTAP data aggregations. The aim of this procedure is to maintain the internal consistency of the data base while minimizing the impacts of the tax change on the value flows in the data base. It utilizes a variant of the GTAP model, for which the model structure and parameter settings have been designed to achieve this aim. The features include Cobb-Douglas production and consumption functions, inter-intermediate input substitution (also Cobb-Douglas), universal factor mobility and fixed trade balances. Instructions and computer files for implementation of the procedure are provided in the attached files.

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# *Adjusting Tax Rates in the GTAP Data Base*

## *1. Introduction*

This paper describes the development of a tax-adjustment procedure for use with the GTAP data base. For various reasons, it is sometimes useful to change the taxes in the initial, pre-simulation data base. In broad terms, the GTAP data base consists of observed trade data and macroeconomic data, combined with the best available data on the domestic economy and on policy settings. The latter are adjusted so as to represent a common base year, and to be consistent with the former. Parts of the data base may be unsatisfactory to a user who has better information than that used to construct the original GTAP data base.

For example, the protection data used in constructing version 3 of the GTAP data base did not take into account the Lomé Convention giving African exporters preferential access to European markets. As a result, tariff rates in the data base were too high. Similarly, protection data available for India pre-dated a liberalization program undertaken in 1991. As the base year for version 3 was 1992, application of this data also resulted in tariff rates which were too high. In both of these cases (see Hertel, Masters, and Elbehri, 1997) researchers adjusted these rates on an *ad hoc* basis.

It is not desirable to simply change one tax and leave the rest of the data base unchanged, because doing this destroys the internal consistency of the data base. In order to maintain the overall balance of the data base, it is necessary to change the tax in question, and allow the other flows in the data base to adjust so as to maintain consistency.

However, in general only one part of the data base will be considered inaccurate. In particular, trade data are *observed* data, whereas domestic and protection data are *estimated*. Also, users will only wish to change data for a subset of regions in the model.

Therefore, it is desirable to limit the effects of the change on other flows in the data base as far as is practical, although some effects are inevitable. It is impossible to have no effects on flows other than the tax itself if internal consistency is to be maintained. By way of example, consider how the pre-tax and post-tax value flows are affected when a tax is changed. By definition, the pre- and post-tax quantities are identical, while the relative prices of the two change. This means that at least one of the two value flows must change.

Implementation of this procedure is similar to a normal experiment: the tax rate in question is 'shocked', and the GTAP model is used to calculate how this affects other flows. A general equilibrium closure ensures that internal consistency is maintained. The difference between a normal experiment and this procedure is that, in the former case, model structure and parameter values are

chosen to represent ‘economic reality’ as accurately as possible, while in the latter case, they are chosen to minimize disturbances to the data base.

It should be noted that the aim of this procedure is to improve the quality of the base year data, where improved information pertaining to that base year becomes available. This procedure is not appropriate for incorporating information which post-dates the base year. If we wished to introduce, for example, information on 1995 tariffs into the 1992 data base, using this procedure to do so would be equivalent to making the assumption that changes in tariffs have minimal effects on trade flow. A preferable approach would be to use the original GTAP model and allow trade flows to change, thereby estimating how the global economy would look with these new tariffs in place. Section 2 provides instructions for use of the procedure

Testing has shown (as detailed in section 3) that the model structure can make a considerable difference to the effects of changing a tax. Also, no particular model has been found to be most suitable in all cases. In particular, the model preferred depends on which tax needs to be changed. The default ALTERTAX model includes features that we considered likely to improve the model’s performance in *most* cases. Users may find value in trying out and assessing the effects of other models. The default model includes the following modifications to the standard GTAP model:

- production and consumption are Cobb-Douglas.
- substitution between different intermediate inputs and the composite primary factor is introduced.
- all endowment commodities are mobile.
- trade balances are exogenized.

There are a number of reasons for including these changes. For some, such as the setting of parameters as Cobb-Douglas, there are clear reasons to expect that they will have an appropriate effect. For others, such as the exogenizing of the trade balance, there is no reason to expect that they will reduce the overall changes in value flows, but we have a preference for retaining the original balance of payments. Finally, others are introduced simply on an empirical basis, with testing having demonstrated that their introduction is beneficial. A listing of the specific changes made to the GTAP94.TAB code is contained in Appendix I.

## ***2. Implementation***

The files necessary to run the ALTERTAX procedure can be obtained from the GTAP web site (Technical Paper No. 12). Download and unzip the file ALTERTAX.ZIP into an empty directory. This should create the following files:

```
MAKEFILE  
ALTERTAX.TAB  
SLUG.TAB
```

TAB.STI  
ALERTAX.STI  
GEMPIE.STI  
CMPHAR.STI  
ALERTAX.CMF

Some of these files need to be customized to recognize the particular data set and set of shocks which the user wants to introduce. The following steps are necessary prior to running the procedure:

**Provide initial data:**

The ALERTAX procedure uses as input the data and sets files obtained when carrying out an aggregation. These two files (generally called DAT?-?.HAR and SET?-?.HAR, where ?-? is the aggregation code) should be saved in the same directory as the other files. It is not necessary to include the parameter file PAR?-?.DAT, since this will not be used by ALERTAX.

**Edit command file ALERTAX.CMF:**

1. Specify input file names DAT?-?.HAR and SET?-?.HAR
2. Change list of DTBAL exogenous components to reflect the set of regions in the aggregation.
3. Specify shocks (these may be either specified directly in the command file or be contained in separate shocks files created by the SHOCKS procedure)

**Edit stored input file CMPHAR.STI:**

1. Change initial data file name DAT?-?.HAR.

**OPTIONAL: Change model structure:**

- A. To exclude inter-input substitution

    Edit ALERTAX.TAB

    Change parameter setting of ESUBT from one to zero.

- B. To introduce the rate-of-return investment rule

    Edit ALERTAX.TAB

    Change parameter setting of RORDELTA from zero to one.

- C. To make all primary factors sluggish:

    Edit MAKEFILE

    Replace reference to ALERTAX.TAB with SLUG.TAB

    Edit TAB.STI

    Replace reference to ALERTAX with SLUG

- D. To endogenize trade balances:

Edit ALTERNAX.CMF

remove DTBAL from list of exogenous variables and make all components of SAVESLACK exogenous

Note: In general, the user should only change the model structure if there are good reasons for doing so, or for purposes of comparison.

### **Implement Model**

Once these steps are complete, the model can be implemented. Depending on the user's system there are a number of ways of doing this:

1. If running GEMPACK source code version (with Lahey utilities available):

Enter the DOS command

```
>make
```

from the directory where the files are stored.

2. If running GEMPACK executable image version:

Edit TAB.STI

Replace the line

```
wfp !write TABLO=generated program
```

with the line

```
pgs !prepare output for GEMSIM
```

Enter the following DOS commands:

```
>tablo <tab.sti
```

```
>gemsim <altertax.sti
```

```
>gempie <gempie.sti
```

```
>cmphar <cmphar.sti
```

from the directory where the files are stored.

### **Outputs**

The procedure should generate the following files:

NEWDATA.UPD	-	updated dataset
ALTERNAX.PRN	-	comparison between NEWDATA.UPD and original data file (this file contains the 'average difference ratio' statistic)
ALTERNAX.PI5	-	shows price and volume changes

In addition, the LOG files are produced. These files can be used to assess the effects of the shock. Users are encouraged to provide feedback to the author on the effectiveness of the procedure, and on any problems encountered.

### 3. Development

The TABLO file used for this procedure is a variant of the standard GTAP model which facilitates a range of alternative specifications. Table 1 describes the different combinations of changes which were tested. Generally, when a change was found to be beneficial it was retained in the subsequent models.

The effects of three arbitrary shocks are separately assessed, these being 100% shocks to the powers of one component of three different taxes: output tax *to*, export tax *txs* and import tariff *tms*. Shocks to these three variables were chosen because, based on past experience, these are the policy variables most likely to be changed by model users. Each of the shocks is implemented under each of the 7 models described above. This is done using GTAP aggregation 3-01. This is a 3 x 3 aggregation which makes analysis of the results relatively simple. The focus industry is the US food sector, and its trade with the EU. Figure 1 shows an outline of the relevant value flows in this data base.

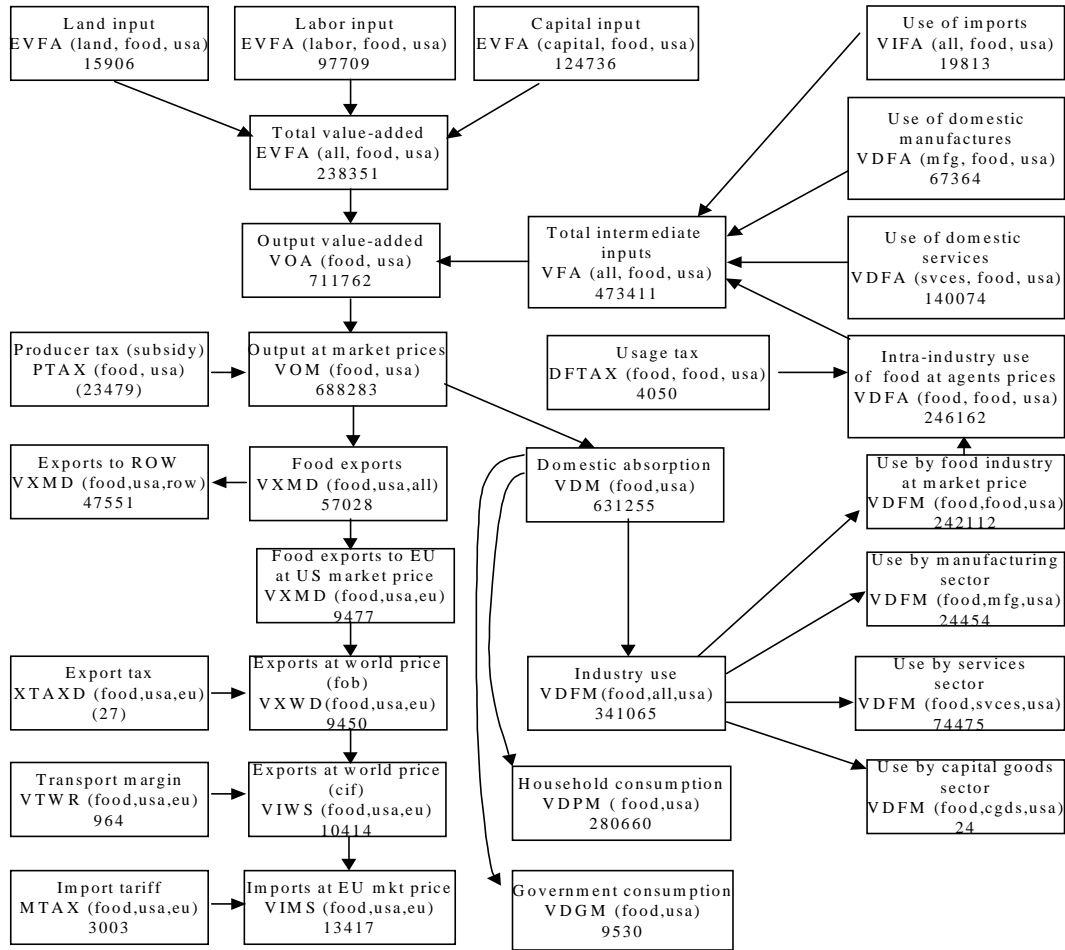
This figure shows the inputs of primary factors (EVFA), imported intermediates (VIFA), and domestically-produced intermediates (VDFA) into the US food industry. It also shows the disposition of the industry's output to: domestic industry (VDFM), households (VDPM), government (VDGM), and exports (VXMD). It also shows taxes or subsidies imposed by the US on output (PTAX), usage of intermediates (DFTAX), exports (XTAXD), and the tax imposed by the EU on imports of food from the US (MTAX). As required by any data base used for applied general equilibrium modeling, these flows are internally consistent.

Table 1 Description of Models

Model Number	Production/ Consumption Substitution	Inter-input Substitution	Trade Balance	Sluggish Factors	Investment Theory
1	CES/CDE	none	endogenous	land	fixed shares
2	Cobb-Douglas	none	endogenous	land	fixed shares
3	“	Cobb-Douglas	endogenous	land	fixed shares
4	“	“	swap with SAVESLACK	land	fixed shares
5	“	“	“	all	fixed shares
6	“	“	“	none	fixed shares
7	“	“	“	“	rate of return



Figure 1 US Food Industry: Initial Value Flows in the Version 3 Data Base



From Figure 1, we can calculate the initial powers of the taxes as follows:

Table 2 Pre-shock tax levels

Tax on ...	Pre-tax value	Post-tax value	Power of tax/subsidy	Tax/subsidy
US food output	711762	688283	1.034	subsidy
US food exports to EU (fob)	9477	9450	1.003	subsidy
EU food imports from US (cif)	10414	13417	1.288	tax

The 100% shocks considered here have the effect of doubling the powers of the taxes, so that they become 2.068, 2.006, and 2.576 for the output, export, and import taxes respectively. So although some of the interventions were originally quite small, all of the shocks are very large.

The GEMPACK procedure COMPHAR (see Harrison and Pearson, 1996) is used to generate a comparison between the initial data set and the updated, post-shock data set. The summary statistic ‘average of all difference ratios’ is used as a general guide to the performance of each closure/parameter set, with smaller values of this statistic being preferred. For each entry of each array common to the original and updated data files, the difference ratio is calculated as

$$|orig - upd| / \min(|orig|, |upd|),$$

where *orig* and *upd* are the original and updated values of the entry respectively. Table 3 shows the values of this statistic for each of the experiments. While useful as a broad guide to the degree of difference between the two data sets, strict minimisation of this variable is not intended, as the user is likely to attach differing importance to the preservation of different arrays in the data set. Also, this statistic may be misleading in situations where the number of value flows in the data base on either side of the shocked tax are not equal. In particular, a high importance is attached to the preservation of trade flows, as that data is of high quality. For some of the experiments, the actual changes in the data base are also presented. We now turn to a discussion of the different models.

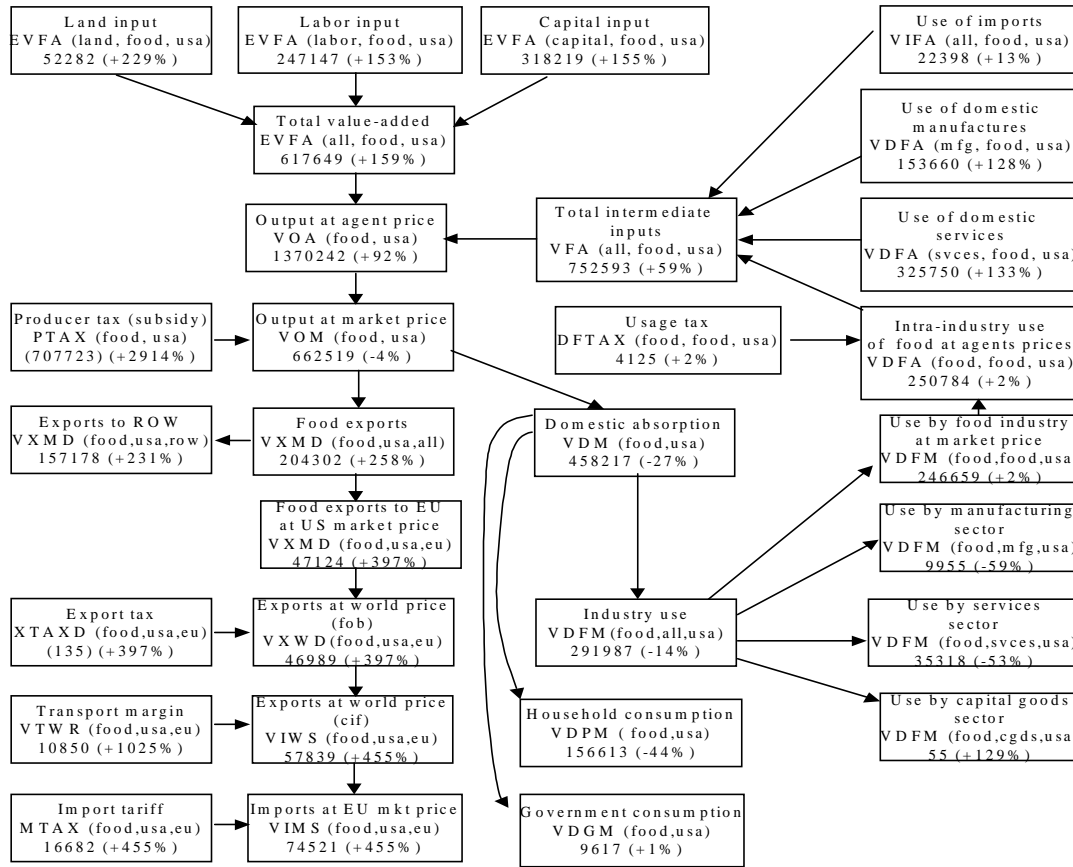
Table 3 Value of average of all difference ratios

Model	to(‘food’,’usa’)	tms(‘food’,’usa’,’eu’)	txs(‘food’,’usa’,’eu’)
1	0.487212	0.217041	0.100339
2	0.101240	0.013297	0.004897
3	0.192223	0.012187	0.003634
4	0.175215	0.012581	0.003784
5	0.176483	0.012588	0.003800
6	0.175215	0.012581	0.003784
7	0.177918	0.012576	0.003795

### Model 1.

This is a model in which the parameters are those specified in the original GTAP parameter file for the aggregation tested. The model structure is the standard one. This is used as a base for comparison for the later models. Figure 2 traces the detailed effects of the shock to the output tax. Total food output at market prices (VOM) is little changed, as almost all of the required adjustment occurs ‘upstream’. In general, this is a desirable property because it means that other countries are less affected. Exports also change very substantially. This is not a desirable outcome.

Figure 2. US Food Industry: Model 1 TO Shock



**Model 2.**

Substitution parameter values (ESUBD, ESUBM, ESUBVA, INCPAR and SUBPAR) are changed so that substitution functions are all Cobb-Douglas. To make the consumption function Cobb-Douglas, SUBPAR is set equal to zero, and INCPAR is set equal to one. The unitary substitution elasticities have the desirable feature that the first-round impact on a flow will be value-preserving: any price change will be offset by an equiproportionate volume change.

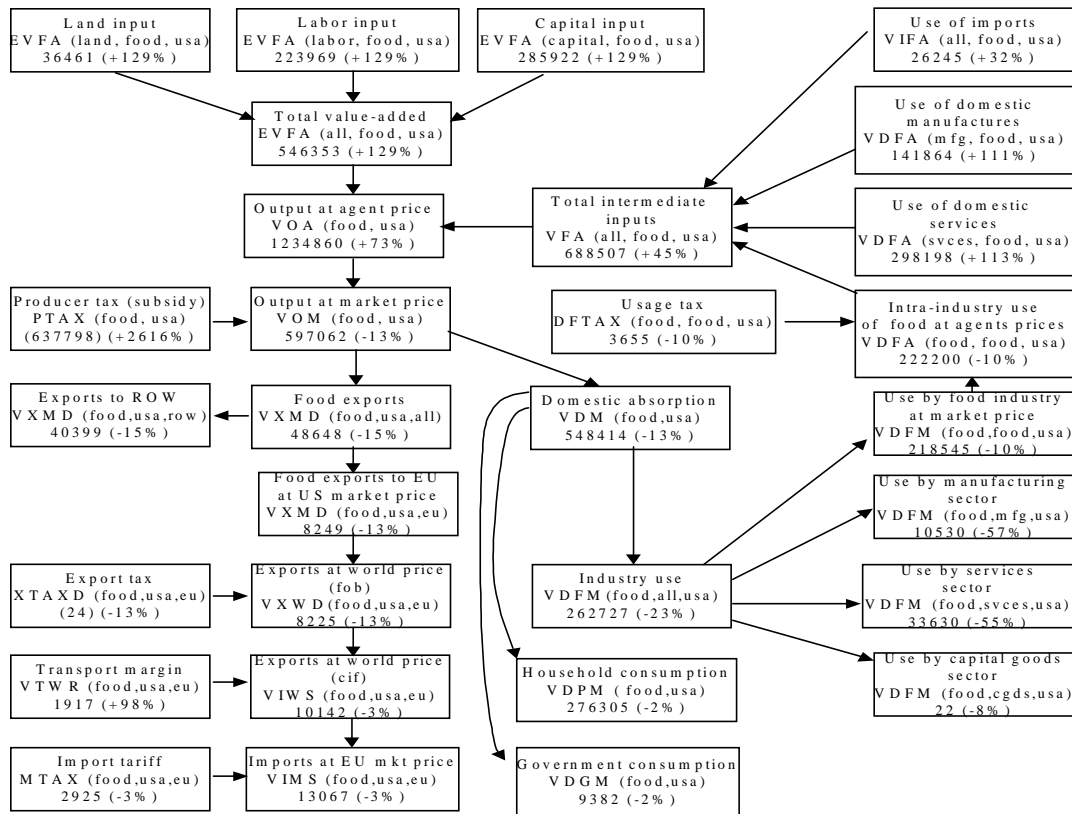
These changes are made by specifying the parameter values within the TABLO program rather than, as is usually done, reading them in from a separate parameter file. This is done so that users do not have to edit the parameter file relevant to each aggregation.

Figure 3 shows how the value flows change in the case of the output tax shock. The domestic effects are qualitatively similar to those of Model 1. Output at market price (VOM) shrinks somewhat,

mainly due to reduced inter-industry use (VDFA (food,food,usa)). However, despite reduced intra-industry use, overall usage of intermediate inputs rises (VFA), as does value-added (EVFA). As a result, output at agent prices rises. Compared to Model 1, the shock in this case somewhat is more evenly spread upstream and downstream. The most significant difference is in exports. In both models, the price of US food falls significantly. In Model 1, import demand for US food is relatively elastic, and so the value of exports rises. In Model 2, however, the introduction of Cobb-Douglas elasticities reduces the quantity response, and as a result the value flow changes much less. There is some change in the value flow because (a) the various tax and transport wedges mean that changes in the US market price and changes in prices facing foreign consumers are not equal and (b) there will be second-round effects (i.e, income effects) in the other economies. Other countries are further insulated by the fact that, because the price of exports falls and the volume rises, transport costs (VTWR) also rise, offsetting most of the decline in *fob* export value. This is clearly a more desirable outcome than that of Model 1.

For shocks to all three taxes, the ‘average difference ratio’ declines significantly relative to model 1.

Figure 3. US Food Industry Model TO Shock



### **Model 3.**

In model 3, a new ‘layer’ of substitution is added to the standard GTAP model, namely substitution in production between each intermediate input and composite value-added. This substitution function is also specified to be Cobb-Douglas. In the standard GTAP model, no substitution occurs at this level.<sup>1</sup>

Interestingly, the addition of this feature worsens the performance of the model with respect to the output tax shock but improves it with respect to the border tax shocks. Why is this? In the case of an output tax, the shock changes the ratio of output at agents prices (VOA) to output at market prices (VOM). Which of these two value flows undergoes most adjustment depends on the relative elasticities of supply and demand.

In Model 3 the Cobb-Douglas substitution function between intermediate inputs has the effect of preserving the relative value ratios of each input into the food industry which means that all input values must change equiproportionately. Thus it is impossible for the value of intra-industry use of food to fall while value-added and other intermediate usage values rise (as occurred in Model 2). Equilibrium is obtained by allowing the size of the food industry to grow, and channeling this growth in output back into intra-industry usage. As can be seen from Figure 4, almost all of the growth in output (VOM) goes to intra-industry use (VDFM (food,food,usa)) The smaller a proportion of output is intra-industry usage, the smaller will be the overall change in output level required. This outcome, although it preserves relative values, distorts the absolute level of flows much more than model 2, and is thus inferior. In both models 2 and 3 the downstream effects outside the US food industry are similar and small.

The domestic effects are outlined in table 4. Although the impacts on factor markets are greater in model 3 the effects on other domestic industries are not very different. This is also because of the inter-input substitution possibility. In this regard, Model 3 is superior to Model 2 in its effects on other industries without inter-intermediate substitution, other US industries make no direct quantity response to lower food prices, and so industry purchases of food fall (in value terms). In contrast, those industries are able to respond in Model 3, and so inter-industry flows are much better preserved (compare changes to VDFM (food, mfg,usa) and VDFM (food,svces, usa) in Figures 3 and 4).

---

<sup>1</sup> See section 2.6 of Hertel, 1997

Figure 4. US Food Industry: Model 3 TO Shock

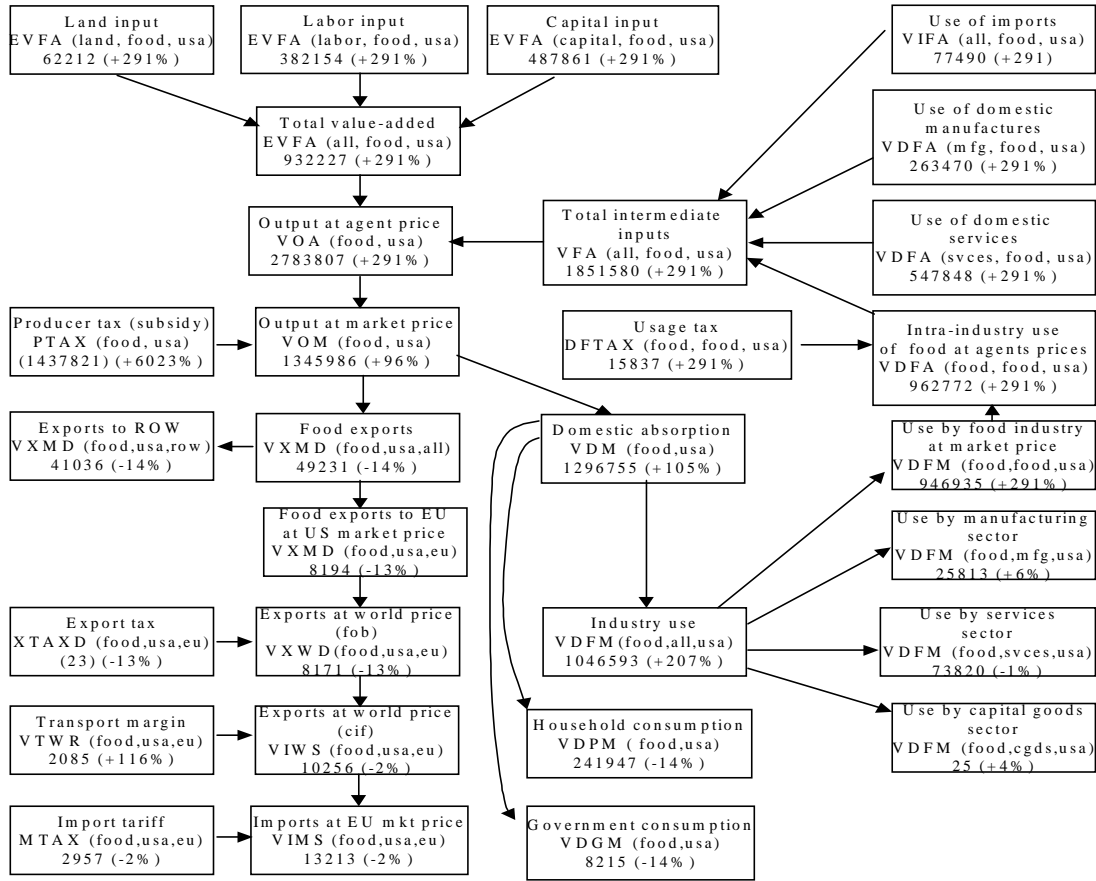


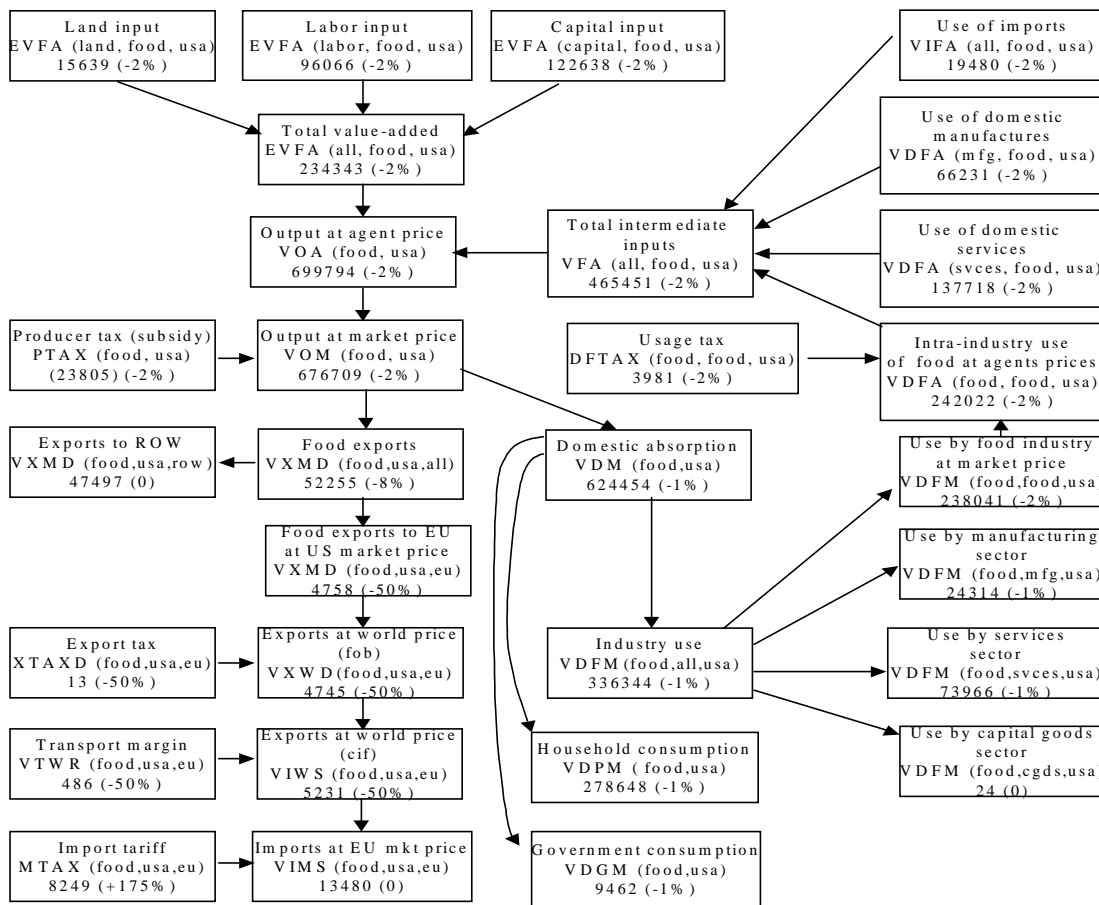
Table 4. Price and quantity changes for TO shock

	Model 2		Model 3	
	Supply price	Output quantity	Supply price	Output quantity
Land	+129	-	+291	-
Labor	+8	-	+9	-
Capital	+13	-	+19	-
Food	-12	+97	-19	+385
Manufacturing	+8	-4	+9	-3
Services	+8	-5	+10	-9

Figure 5 shows the effects on the value flows in the case of the import tariff shock using Model 3. In this case the tax wedge between output at agents prices and at market prices does not change, and so the problem above does not arise. The volume of exports falls, and this has an impact on domestic output. Because exports to the EU are a small proportion of total US food output, the impacts outside of those flows directly affected are all small. This outcome seems satisfactory.

The default set-up for the procedure includes inter-input Cobb-Douglas substitution. This is suitable for shocks to border taxes, but may not be suitable for shocks to output taxes. This setting can be changed by the user, as described in the ‘implementation’ section below.

Figure 5 US Food Industry: Model 3 TMS Shock



#### **Model 4.**

This exogenizes trade balances in all but one region. It is not possible to exogenize trade balances in all regions because the model becomes singular. This is because the sum of all trade balances globally must equal zero. This closure is added primarily because of a desire to preserve the trade balance data, not to improve the overall ‘accuracy’ of the model. Thus we impose this condition regardless of its effect on the average difference ratios.<sup>2</sup> In order to exogenize the trade balance, we endogenize the *saveslack* variable. Under this closure, savings rates adjust passively so as to ensure that the identity  $S-I=X-M$  holds. Doing this does not appear to lead to a loss of the GE nature of the closure so that *walraslack* is zero.

The effect of doing this appears beneficial in the case of a shock to output tax, but not beneficial in the cases of trade tax shocks (at least as far as the ‘average difference ratio’ criterion is concerned). These results are intuitively plausible: in the case of the output tax, exogenizing the trade balance restricts the flow-on effects outside the country concerned, while in the case of border tax shocks the inevitable change to trade flows is required to be compensated for in other industries. This closure is preserved in the following models.

#### **Model 5**

In this model, all primary factors are treated as being sluggish with a unitary elasticity of transformation (in the earlier models, only land was sluggish, while labor and capital were mobile). Factor returns do not equalize across sectors, and thus changes in the size of one domestic industry will not have as strong an effect on other domestic industries *via* factor markets. The quantity response of the sector affected by the shock becomes more constrained. However, by the same token, factor prices within the primarily-affected industry will vary more, and so will output prices in that industry. This will have a flow-on effect on other industries to the extent that they purchase intermediate inputs from the affected industry.

The question of whether the net effects are larger or smaller than when factors are mobile is an empirical one. For all three of the shocks tested, the ‘average difference ratio’ rose relative to model 4. On this basis, this model is not preferred and sluggish factor feature is dropped in subsequent models.

#### **Model 6**

In this model, the opposite assumption is made: that all primary factors are mobile. In the aggregation used, the only factor initially sluggish is land, and this factor is used only by the food sector. Thus, in this aggregation, it is impossible for land to move between sectors even when specified to be a mobile factor. Therefore, the results of this model are identical to the results of model 4 (see table 3).

---

<sup>2</sup>Initially, trade balances were ‘swapped’ with the slack parameter in the investment equation, *cgdslack*. However, doing this resulted in a non-zero value for the *walraslack* parameter which is used as a check on the GE nature of the closure. This is not acceptable in the present case because we wish to preserve the overall balance of the data base. Therefore we do not exogenize trade balances using *cgdslack*.



When tested on an aggregation with sluggish factors used in multiple sectors, it was found that making all primary factors mobile reduced the average of all difference ratios relative to the original case. Therefore, the all-mobile model is preferred, and is used as the default setting. However, another TABLO file is provided which allows the user to change this setting.

#### **Model 7**

This model is designed to assess the effects of changing the way in which investment occurs. In prior models, the RORDELTA parameter has been set at zero, i.e. regional investment shares have been fixed. In this model, RORDELTA is set at one, i.e. the ‘rate of return’ investment model applies. Changing this parameter was found to have a small beneficial effect in the case of an import tariff shock, but larger harmful effects in the other two cases. Therefore the assumption that regional investment shares remain constant is retained in the default setting.

### ***4. Summary***

In summary, this technical paper proposes a specific set of procedures for modifying tax rates in the GTAP data base. It utilizes a modified version of the GTAP model, in which parameters and closures are altered in order to minimize the impact of these tax adjustments on the value flows in the data base. The associated files for implementing ALTERTAX may be downloaded from the GTAP web site:

<http://www.agecon.purdue.edu/gtap/techpaper>

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## ***Appendix I : Changes made to GTAP94WD.TAB***

The following changes are made to the TABLO program:

1. 'Hardwired' parameter values by removing references to GTAPPARM file, and specifying all substitution parameter values within the TABLO file:

```
formula (all,i,trad_comm)(all,r,reg) subpar(i,r) = 0 ;
formula (all,i,trad_comm)(all,r,reg) incpar(i,r) = 1 ;
formula (all,i,trad_comm) esubd(i) = 1 ;
formula (all,i,trad_comm) esubm(i) = 1 ;
formula (all,i,prod_comm) esubva(i) = 1 ;
formula (all,r,reg) rorflex(r) = 10 ;
formula rordelta = 0 ;
formula (all,i,prod_comm) esubt(i) = 1 ;
```

2. Introduced substitution between intermediate inputs and primary factors:

```
EQUATION VADEMAND
! Sector demands for primary factor composite. (HT#35)!
(all,j,PROD_COMM)(all,r,REG)
    qva(j,r) + ava(j,r) = qo(j,r) - ao(j,r)
                        - ESUBT(j) * [pva(j,r) - pinp(j,r)];

EQUATION INTDEMAND
! Industry demands for intermediate inputs, including cgds. (HT#36) !
(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
    qf(i,j,r) = D_VFA(i,j,r) * [ - af(i,j,r) + qo(j,r) - ao(j,r) -
                                ESUBT(j) * (pf(i,j,r) - pinp(j,r)) ];
```

where *ESUBT* is

```
COEFFICIENT (all,i,prod_comm)                                ESUBt (i)
! This is the (constant) elasticity of substitution in production between
  intermediate inputs and composite value-added. !;
```

and *pinp* is

```
VARIABLE (ALL,J,prod_COMM)(ALL,R,REG)                                pinp(j,r)
    #Index of production input prices # ;
```

```
EQUATION INPUTPRICES
! PRICE INDEX FOR ALL INPUTS!
(all,j,prod_comm)(all,r,reg)
    pinp(j,r) = shripva(j,r) * pva(j,r) +
                sum(k,trad_comm,(shrip(k,j,r) * pf(k,j,r)));
```

with the share coefficients *shrip* and *shripva* defined as:

```
COEFFICIENT (all,i,TRAD_COMM)(ALL,J,prod_COMM)(all,r,REG)        SHRINP(i,J,r)
    ! THE SHARE OF EACH INTERMEDIATE INPUT IN PRODUCTION! ;
FORMULA (all,i,TRAD_COMM)(ALL,J,prod_COMM)(all,r,REG)
```

```

SHRINP(i,J,r) = VFA(i,J,r)/SUM(K,DEMD_COMM, VFA(K,J,R)) ;

COEFFICIENT (all,J,prod_COMM)(all,r,REG)          SHRINPVA(J,r)
! THE SHARE OF COMPOSITE VALUE ADDED IN PRODUCTION ! ;
FORMULA (all,J,prod_COMM)(all,r,REG)
SHRINPVA(J,r) = SUM[K,ENDW_COMM,
VFA(K,J,r)/SUM(L,DEMD_COMM, VFA(L,J,r))];

```

3. Removed distinction between sluggish and mobile primary factors, treating all as mobile (in SLUG.TAB, all are treated as sluggish).